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**Peden et al.**

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(54) **DIGITAL SYSTEM AND METHOD FOR PAINT COLOR MATCHING**

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(73) Assignee: **SWIMC LLC**, Cleveland, OH (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 348 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Sep. 20, 2019**

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(Continued)

(51) **Int. Cl.**
***G06T 7/90*** (2017.01)
***H04N 1/60*** (2006.01)

(52) **U.S. Cl.**
CPC ..... ***G06T 7/90*** (2017.01); ***H04N 1/6033*** (2013.01); ***H04N 1/6047*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ..... G06T 7/90; G06T 2207/10024; H04N 1/6033; H04N 1/6047; H04N 1/6052; H04N 1/6055; H04N 1/6083
See application file for complete search history.

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*Primary Examiner* — Christopher Wait
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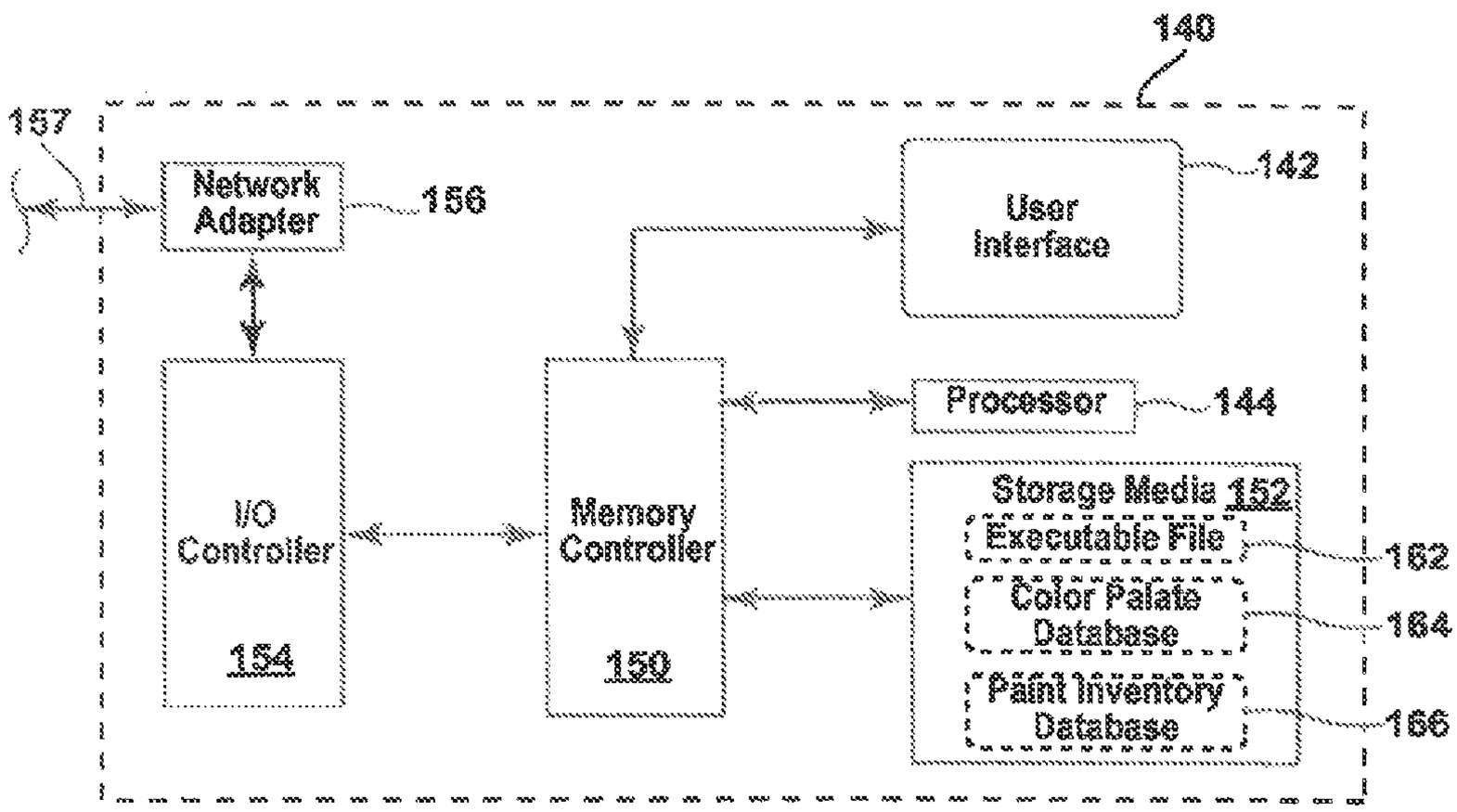
(57) **ABSTRACT**

A method includes obtaining first color information for each of a plurality of first samples of a first target color with a color measurement device connected to a computing device including a display. A digital color image of at least one first target color is displayed on the display. An offset value for each first target color is determined such that the digital color image of each first target color matches the corresponding first target color on each of the first samples. A second sample including a second target color is scanned to obtain second color information. A processor of the computing device determines, using the offset values of the first target colors, an interpolated offset for the display such that the digital image of the second target color matches the second target color.

**25 Claims, 20 Drawing Sheets**



**Related U.S. Application Data**

(60) Provisional application No. 62/132,672, filed on Mar. 13, 2015, provisional application No. 62/017,245, filed on Jun. 25, 2014.

(52) **U.S. Cl.**
CPC ..... ***H04N 1/6052*** (2013.01); ***H04N 1/6055*** (2013.01); ***H04N 1/6083*** (2013.01); *G06T 2207/10024* (2013.01)

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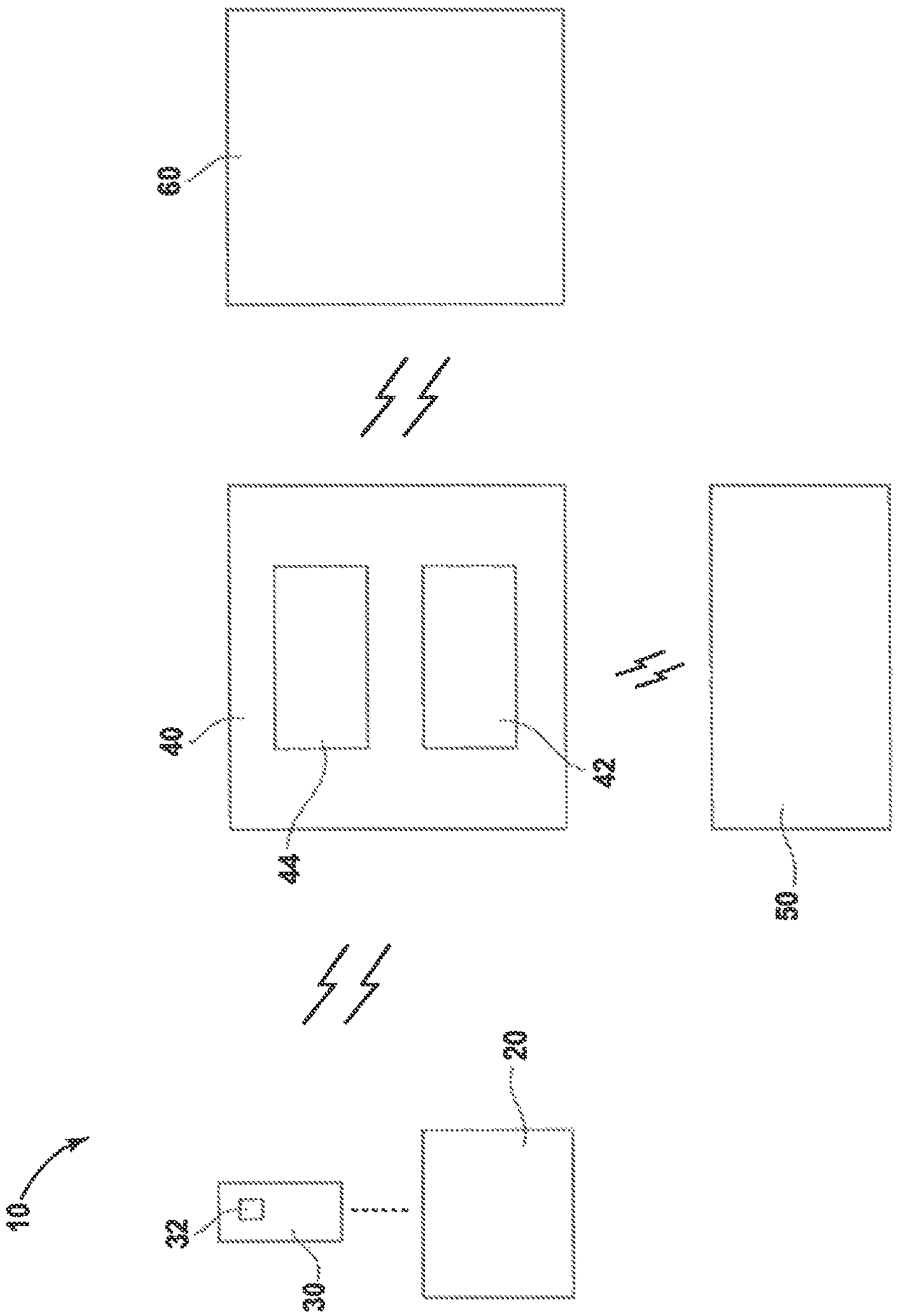


FIG. 1

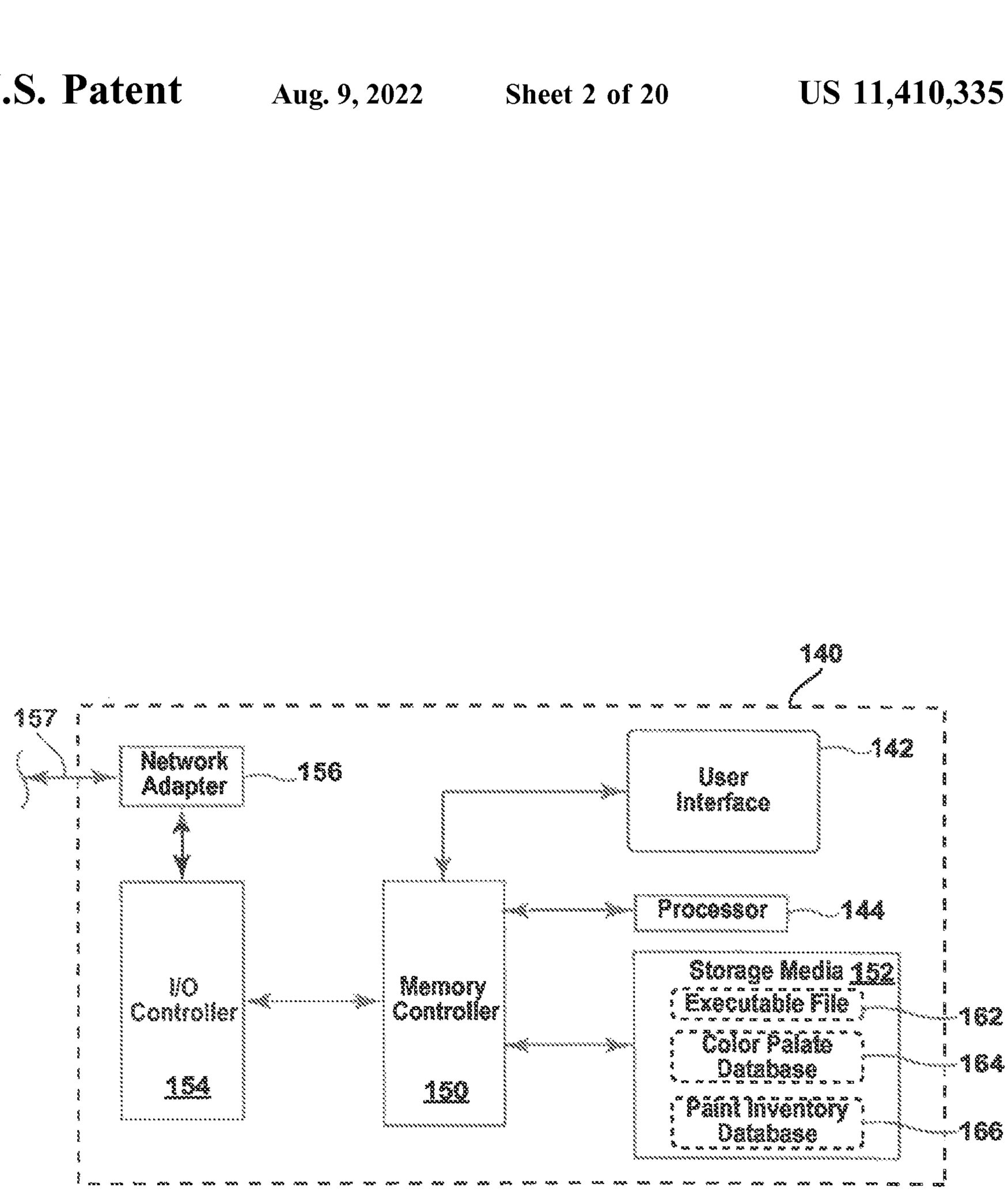
140
157
Network Adapter
156
User Interface
142
I/O Controller
154
Memory Controller
150
Processor
144
Storage Media 152
Executable File
162
Color Palate Database
164
Paint Inventory Database
166

FIG. 1A

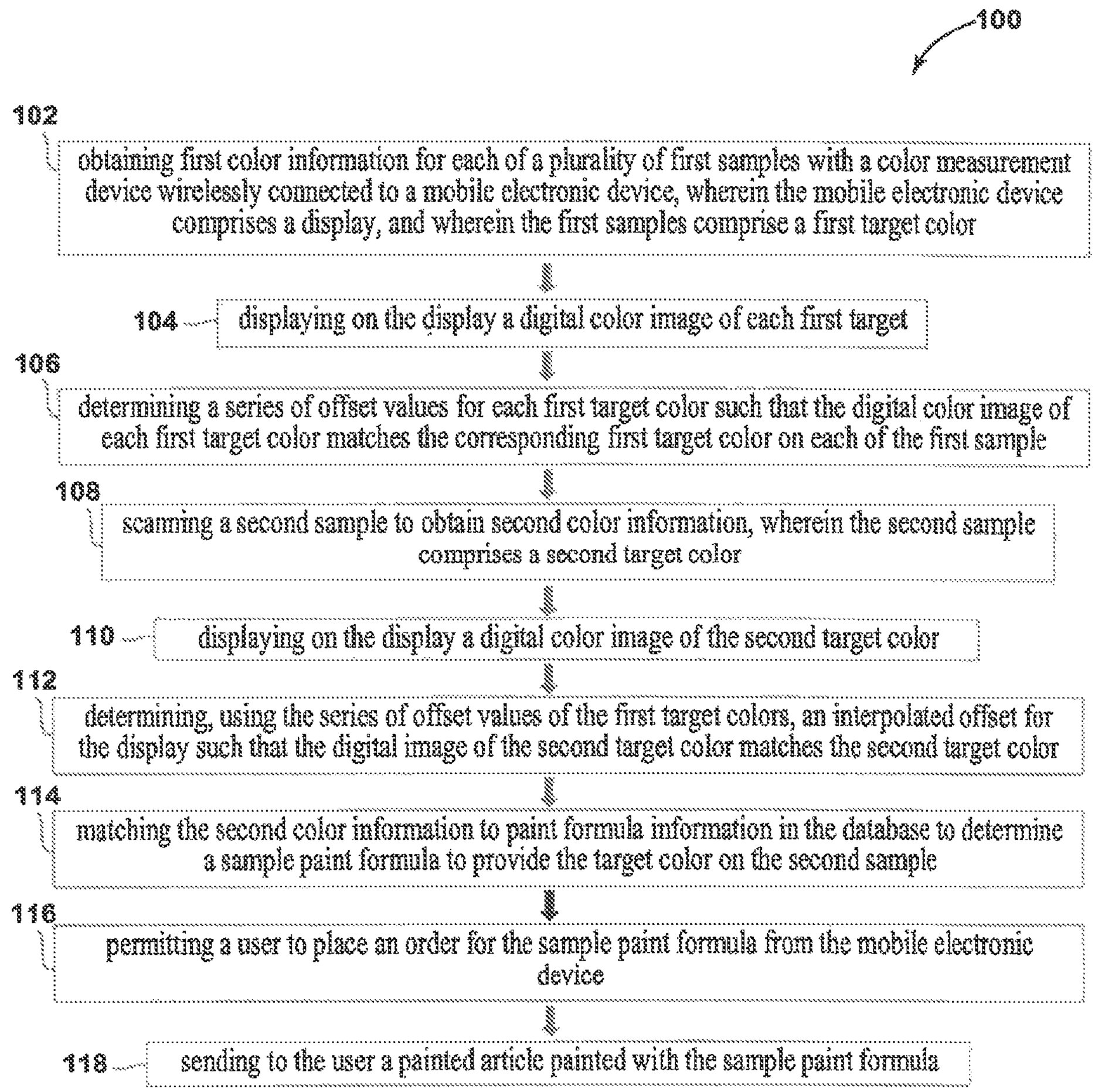
100
102
obtaining first color information for each of a plurality of first samples with a color measurement device wirelessly connected to a mobile electronic device, wherein the mobile electronic device comprises a display, and wherein the first samples comprise a first target color
104
displaying on the display a digital color image of each first target
106
determining a series of offset values for each first target color such that the digital color image of each first target color matches the corresponding first target color on each of the first sample
108
scanning a second sample to obtain second color information, wherein the second sample comprises a second target color
110
displaying on the display a digital color image of the second target color
112
determining, using the series of offset values of the first target colors, an interpolated offset for the display such that the digital image of the second target color matches the second target color
114
matching the second color information to paint formula information in the database to determine a sample paint formula to provide the target color on the second sample
116
permitting a user to place an order for the sample paint formula from the mobile electronic device
118
sending to the user a painted article painted with the sample paint formula

FIG. 2

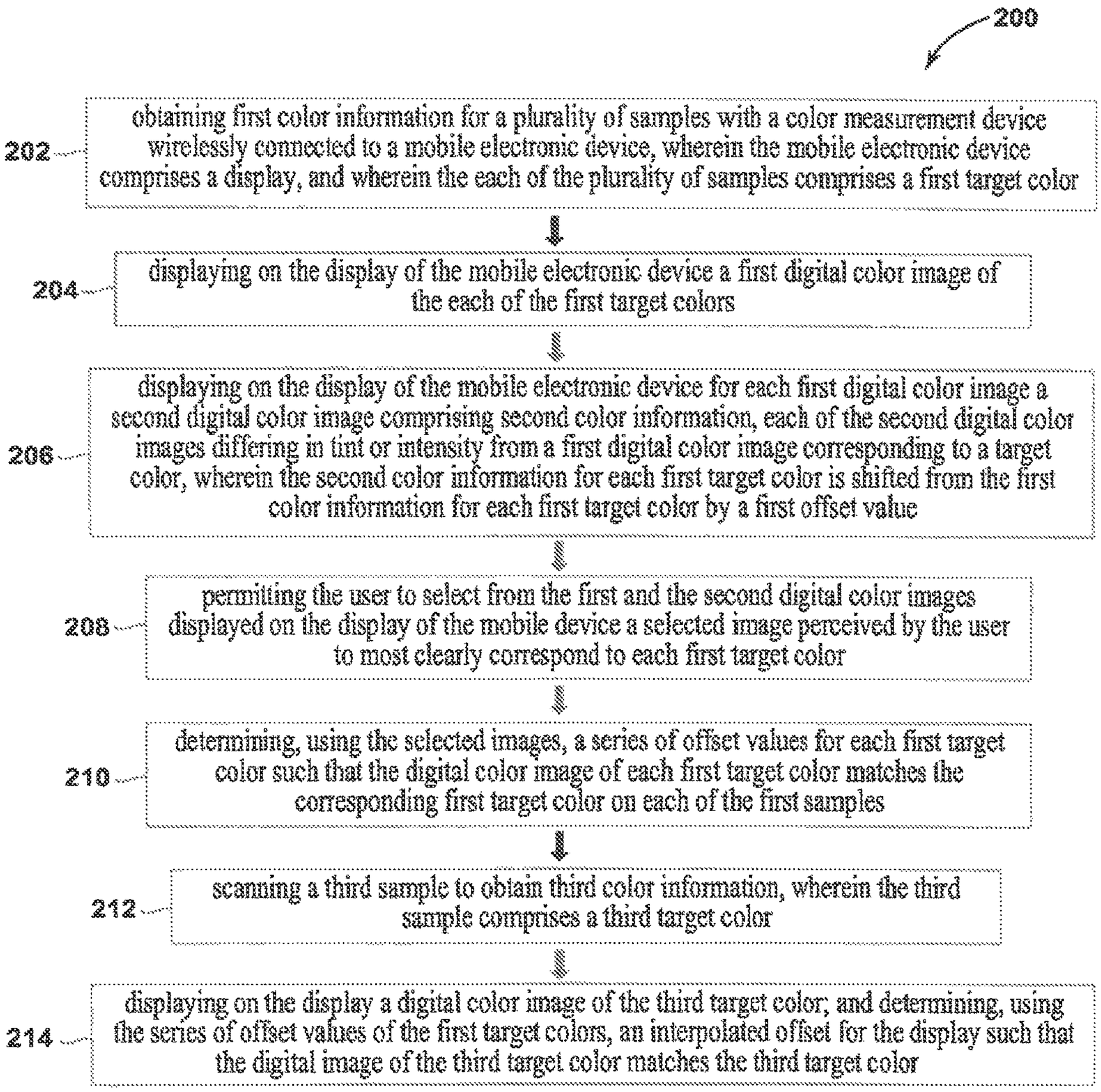
200
202
obtaining first color information for a plurality of samples with a color measurement device wirelessly connected to a mobile electronic device, wherein the mobile electronic device comprises a display, and wherein the each of the plurality of samples comprises a first target color
204
displaying on the display of the mobile electronic device a first digital color image of the each of the first target colors
206
displaying on the display of the mobile electronic device for each first digital color image a second digital color image comprising second color information, each of the second digital color images differing in tint or intensity from a first digital color image corresponding to a target color, wherein the second color information for each first target color is shifted from the first color information for each first target color by a first offset value
208
permitting the user to select from the first and the second digital color images displayed on the display of the mobile device a selected image perceived by the user to most clearly correspond to each first target color
210
determining, using the selected images, a series of offset values for each first target color such that the digital color image of each first target color matches the corresponding first target color on each of the first samples
212
scanning a third sample to obtain third color information, wherein the third sample comprises a third target color
214
displaying on the display a digital color image of the third target color; and determining, using the series of offset values of the first target colors, an interpolated offset for the display such that the digital image of the third target color matches the third target color

FIG. 3


FIG. 4A

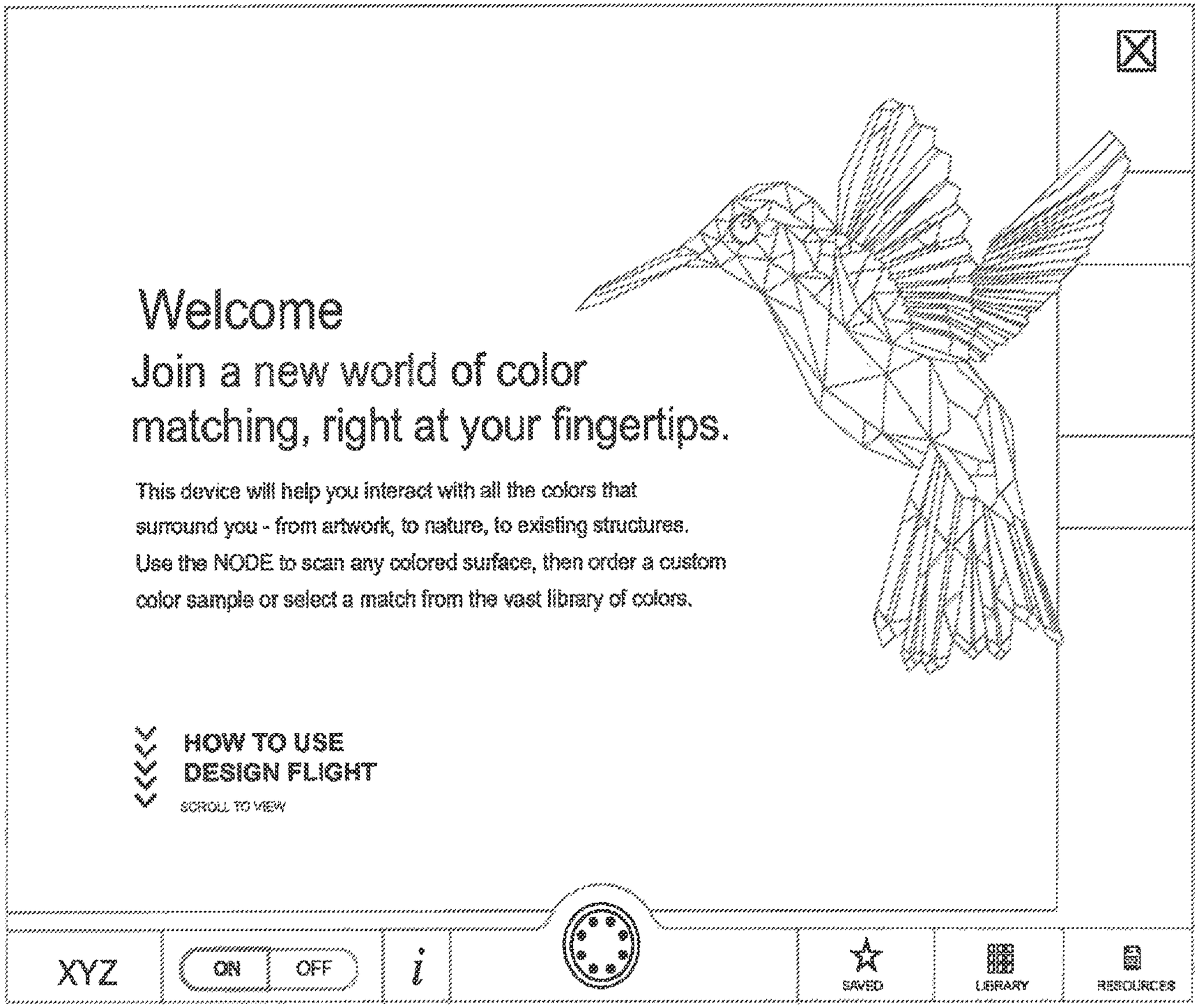
Welcome
Join a new world of color matching, right at your fingertips.
This device will help you interact with all the colors that surround you - from artwork, to nature, to existing structures. Use the NODE to scan any colored surface, then order a custom color sample or select a match from the vast library of colors.
HOW TO USE
DESIGN FLIGHT
SCROLL TO VIEW
XYZ
ON
OFF
i
SAVED
LIBRARY
RESOURCES

FIG. 4B

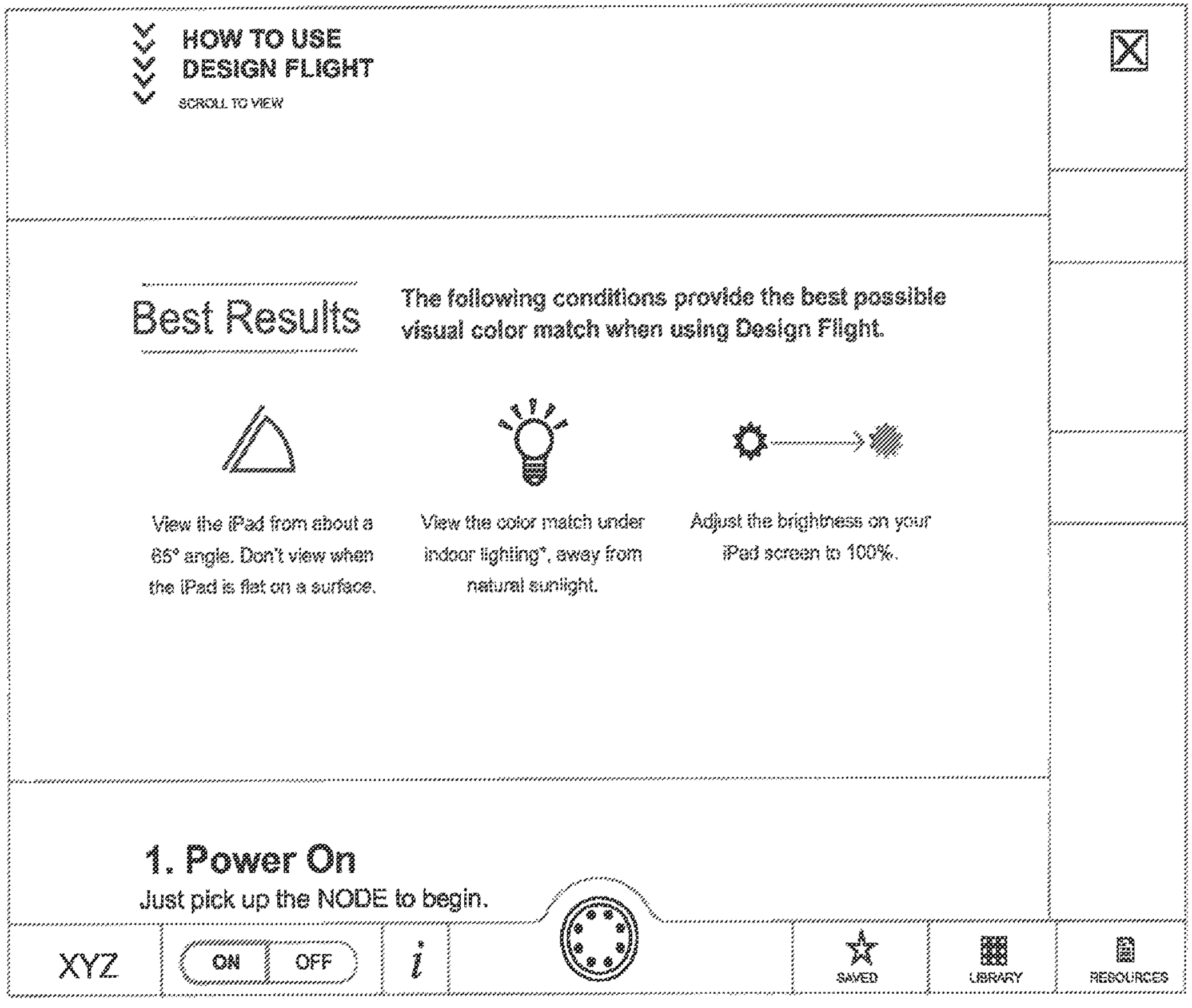
HOW TO USE
DESIGN FLIGHT
SCROLL TO VIEW
Best Results
The following conditions provide the best possible visual color match when using Design Flight.
View the iPad from about a 65° angle. Don't view when the iPad is flat on a surface.
View the color match under indoor lighting*, away from natural sunlight.
Adjust the brightness on your iPad screen to 100%.
1. Power On
Just pick up the NODE to begin.
XYZ
ON
OFF
i
SAVED
LIBRARY
RESOURCES

FIG. 5

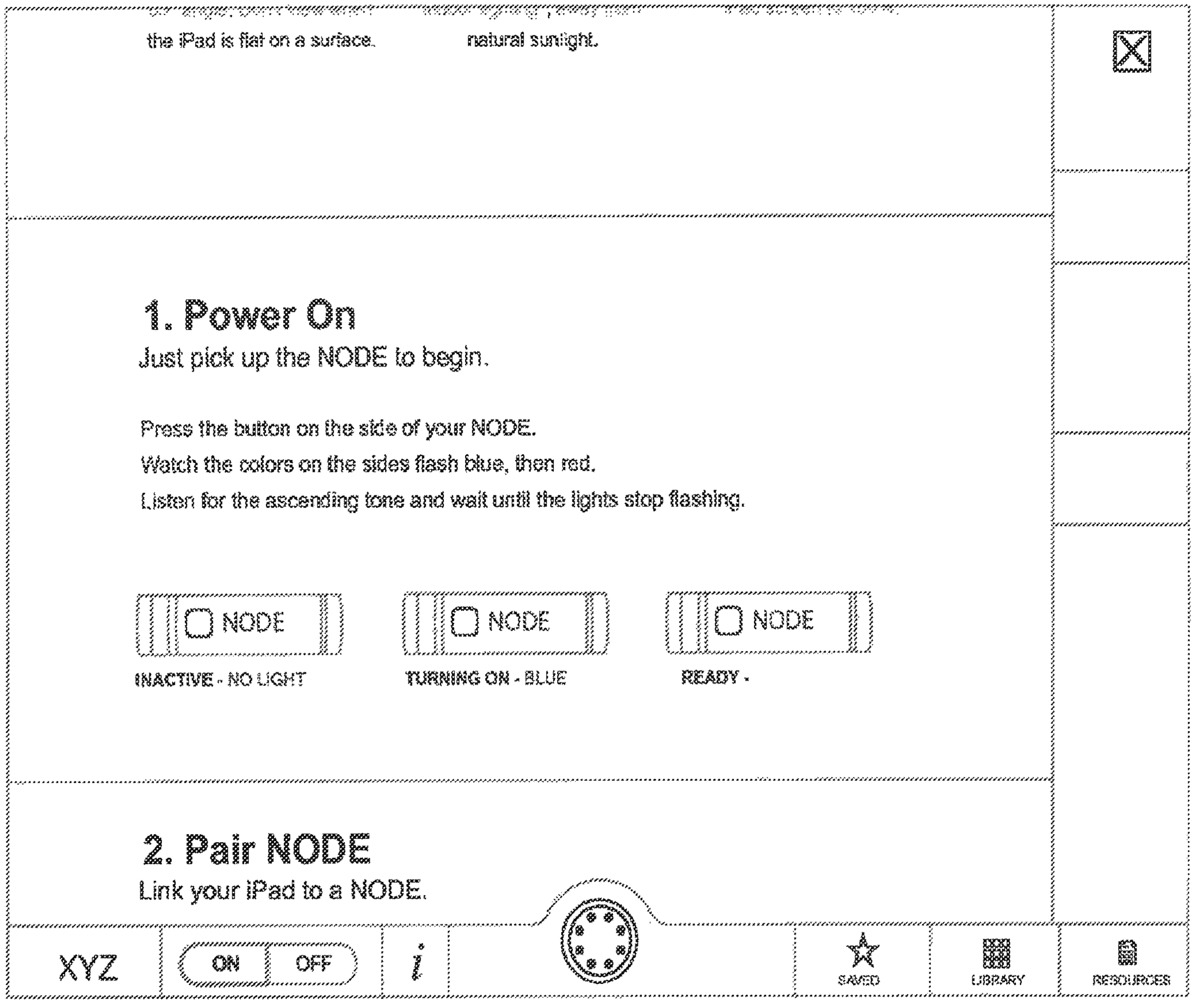
the iPad is flat on a surface.
natural sunlight.
1. Power On
Just pick up the NODE to begin.
Press the button on the side of your NODE.
Watch the colors on the sides flash blue, then red.
Listen for the ascending tone and wait until the lights stop flashing.
NODE
NODE
NODE
INACTIVE - NO LIGHT
TURNING ON - BLUE
READY -
2. Pair NODE
Link your iPad to a NODE.
XYZ
ON
OFF
i
SAVED
LIBRARY
RESOURCES

FIG. 6

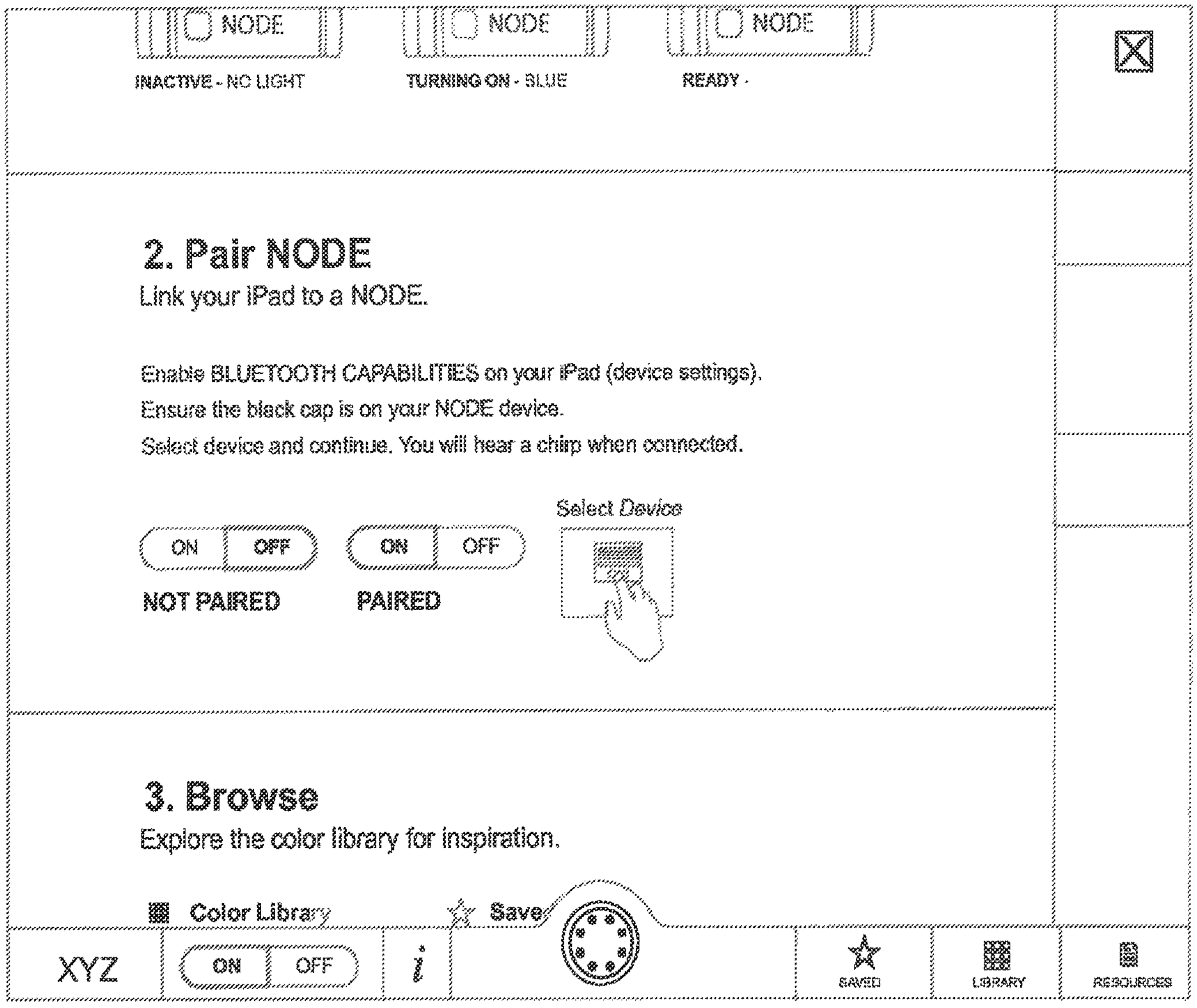
NODE
NODE
NODE
INACTIVE - NO LIGHT
TURNING ON - BLUE
READY -
2. Pair NODE
Link your iPad to a NODE.
Enable BLUETOOTH CAPABILITIES on your iPad (device settings).
Ensure the black cap is on your NODE device.
Select device and continue. You will hear a chirp when connected.
Select Device
ON
OFF
ON
OFF
NOT PAIRED
PAIRED
3. Browse
Explore the color library for inspiration.
Color Library
Save
XYZ
ON
OFF
i
SAVED
LIBRARY
RESOURCES

FIG. 7

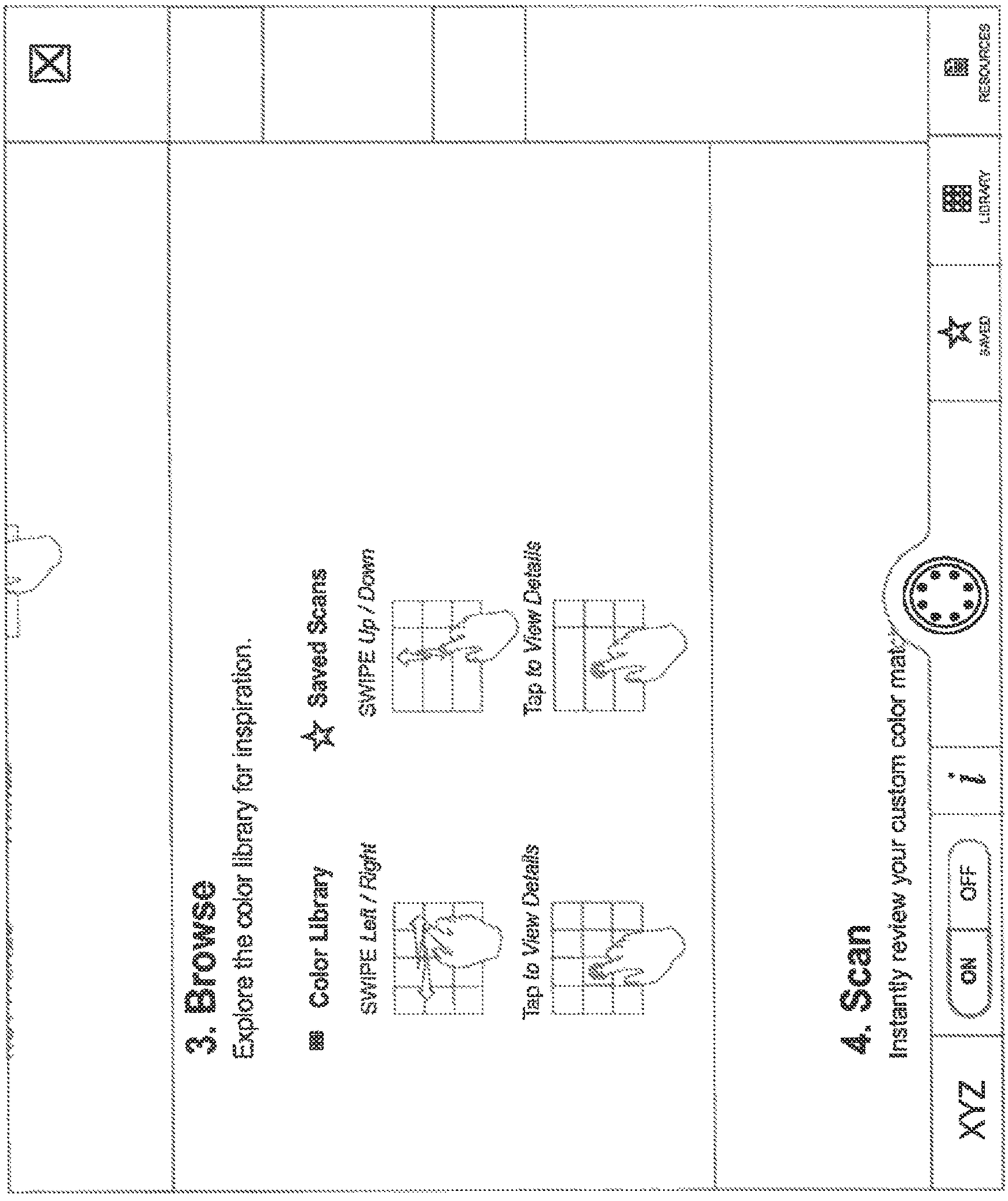
RESOURCES
LIBRARY
SAVED
3. Browse
Explore the color library for inspiration.
Saved Scans
SWIPE Up / Down
Tap to View Details
Color Library
SWIPE Left / Right
Tap to View Details
4. Scan
Instantly review your custom color matches
XYZ
on
OFF

FIG. 8

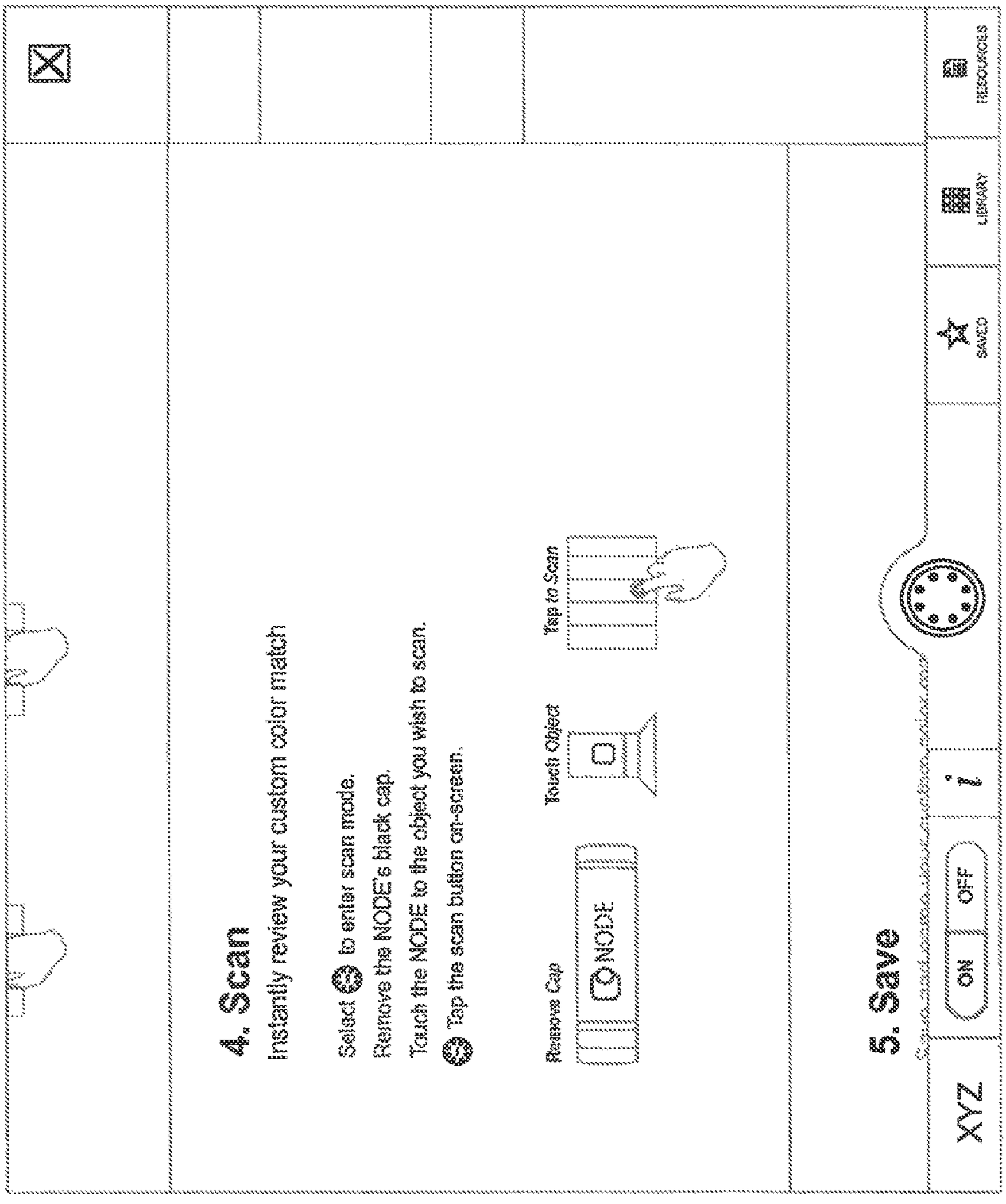
RESOURCES
LIBRARY
SAVED
Touch Object
Tap to Scan
NODE
4. Scan
Instantly review your custom color match
Select to enter scan mode.
Remove the NODE's black cap.
Touch the NODE to the object you wish to scan.
Tap the scan button on-screen.
Remove Cap
NODE
5. Save
XYZ
ON
OFF

FIG. 9

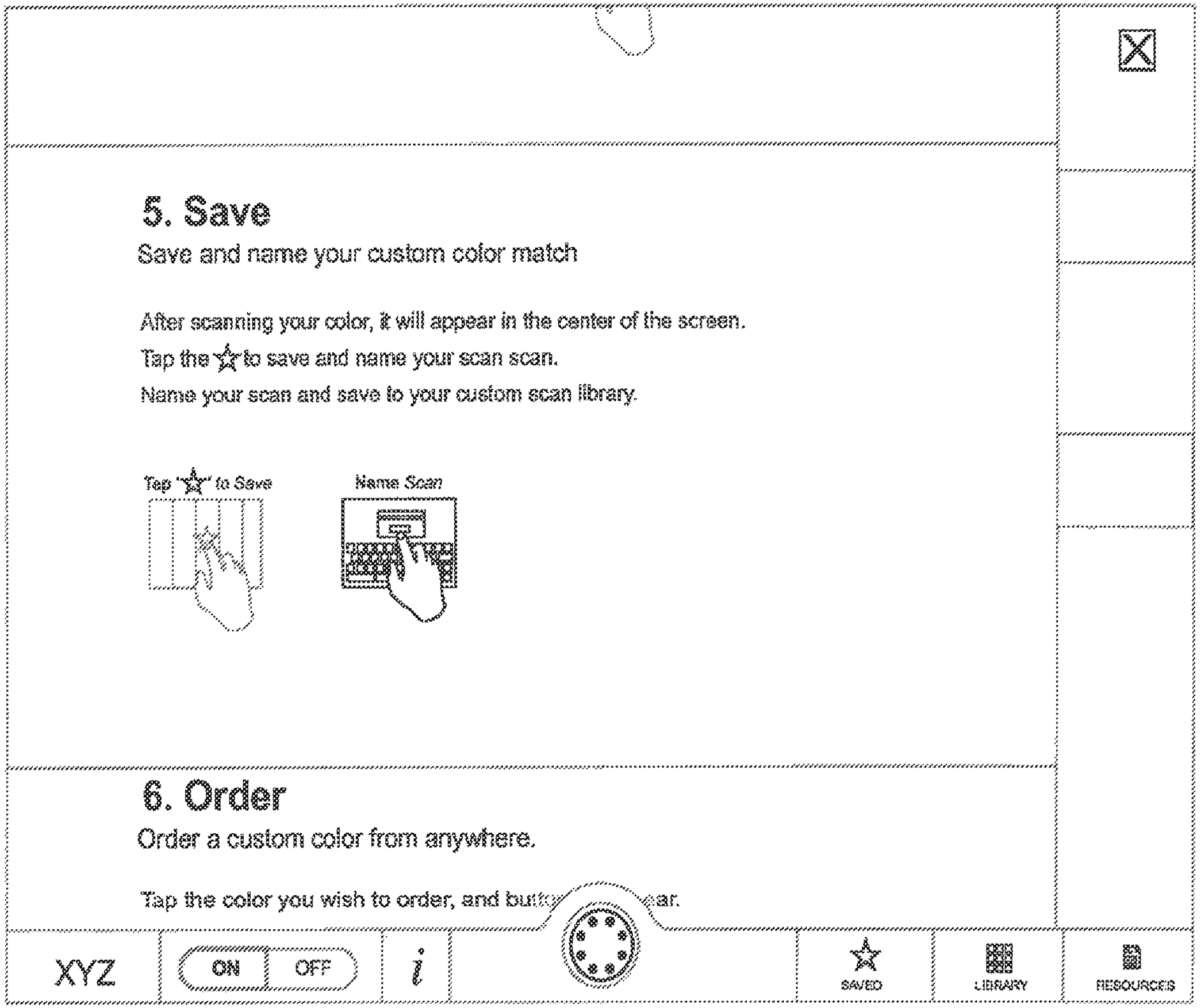
5. Save
Save and name your custom color match
After scanning your color, it will appear in the center of the screen.
Tap the ☆ to save and name your scan scan.
Name your scan and save to your custom scan library.
Tap "☆" to Save
Name Scan
6. Order
Order a custom color from anywhere.
Tap the color you wish to order, and butt
ar.
XYZ
ON
OFF
i
SAVED
LIBRARY
RESOURCES

FIG. 10

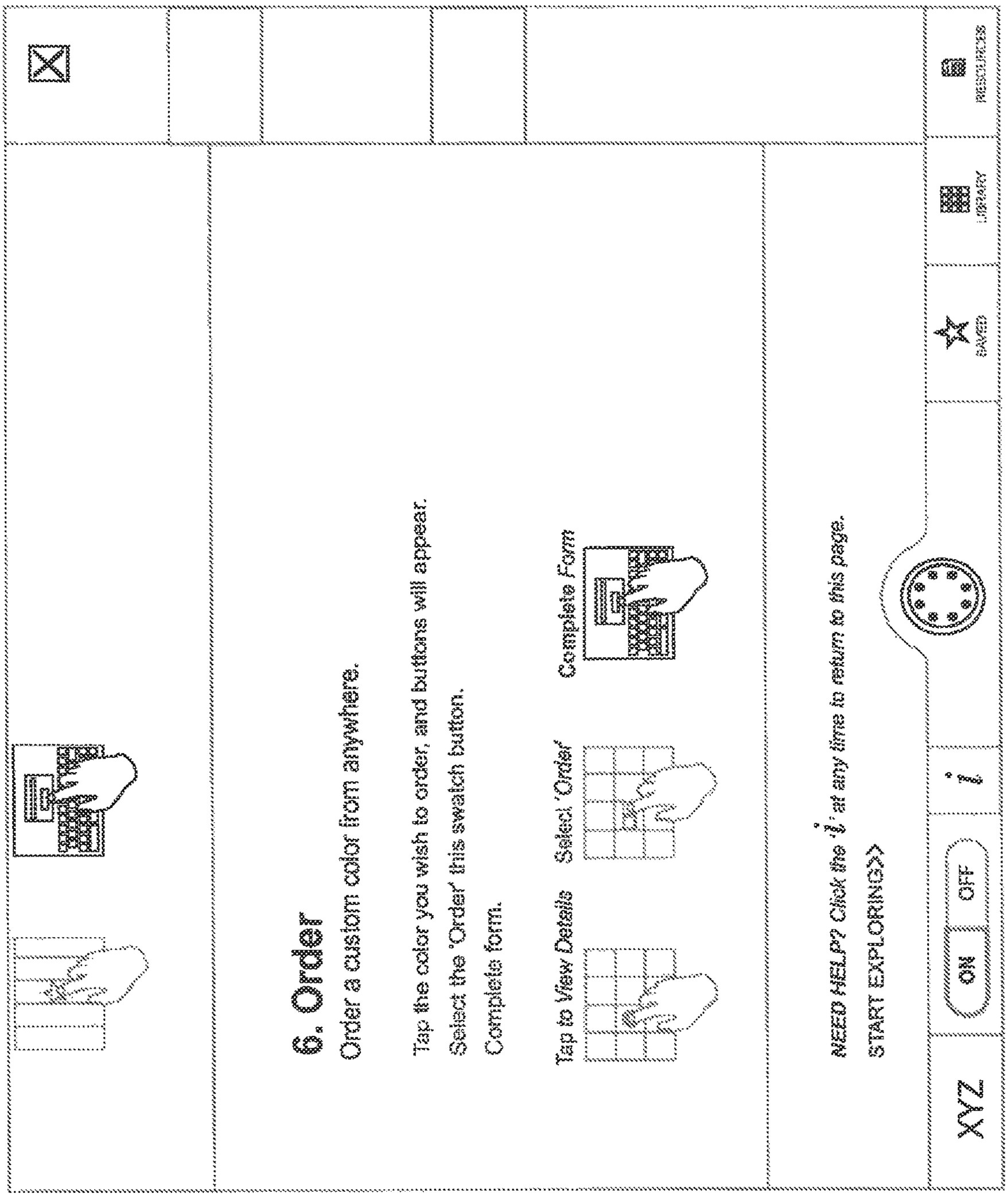
6. Order
Order a custom color from anywhere.
Tap the color you wish to order, and buttons will appear.
Select the 'Order' this swatch button.
Complete form.
Tap to View Details
Select 'Order'
Complete Form
NEED HELP? Click the 'i' at any time to return to this page.
START EXPLORING!
XYZ
ON
OFF
SAVED
LIBRARY

FIG. 11

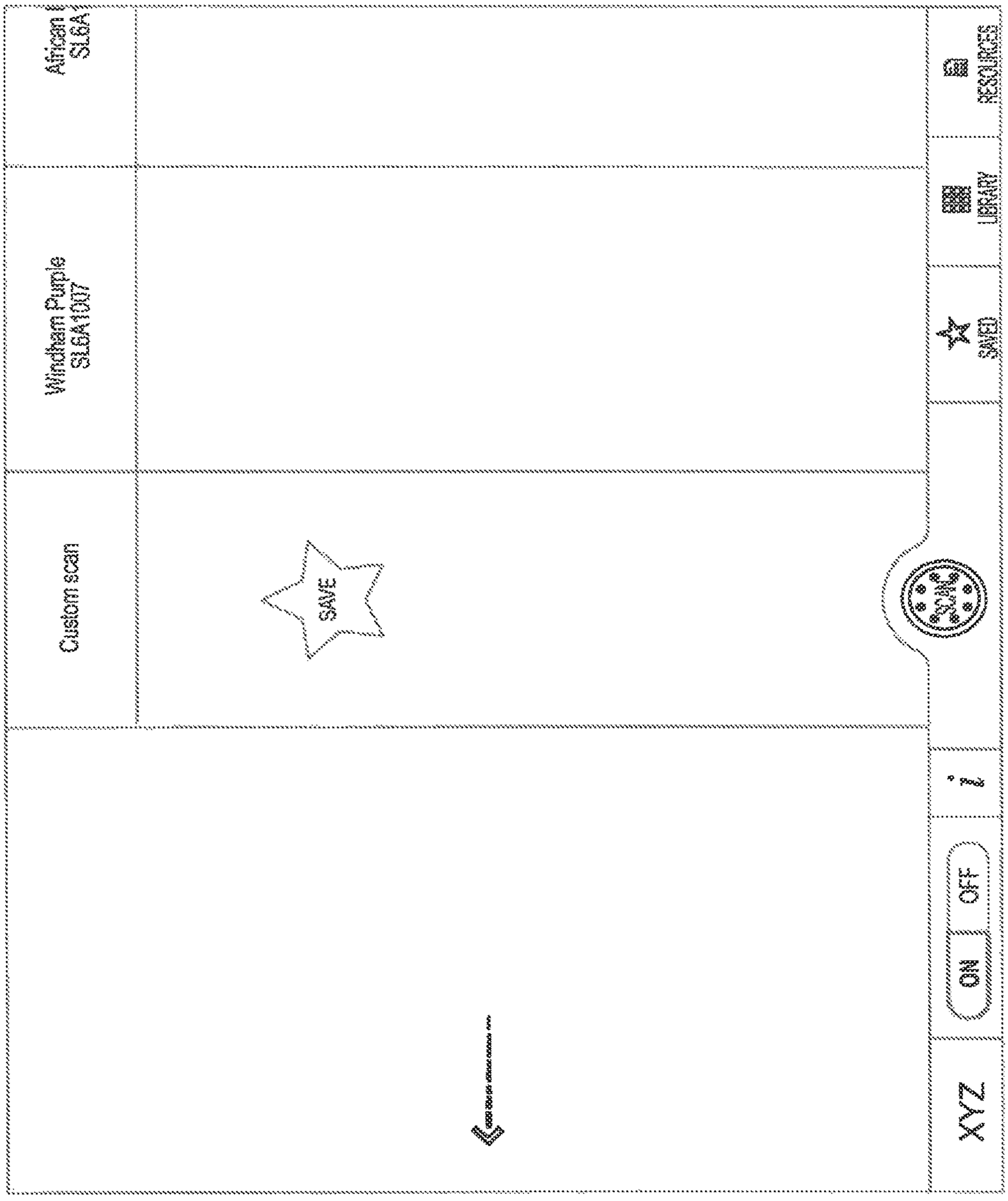
African
SL6A
Windham Purple
SL6A1017
Custom scan
SAVE
RESOURCES
LIBRARY
SAVED
?
ON
OFF
XYZ

FIG. 12

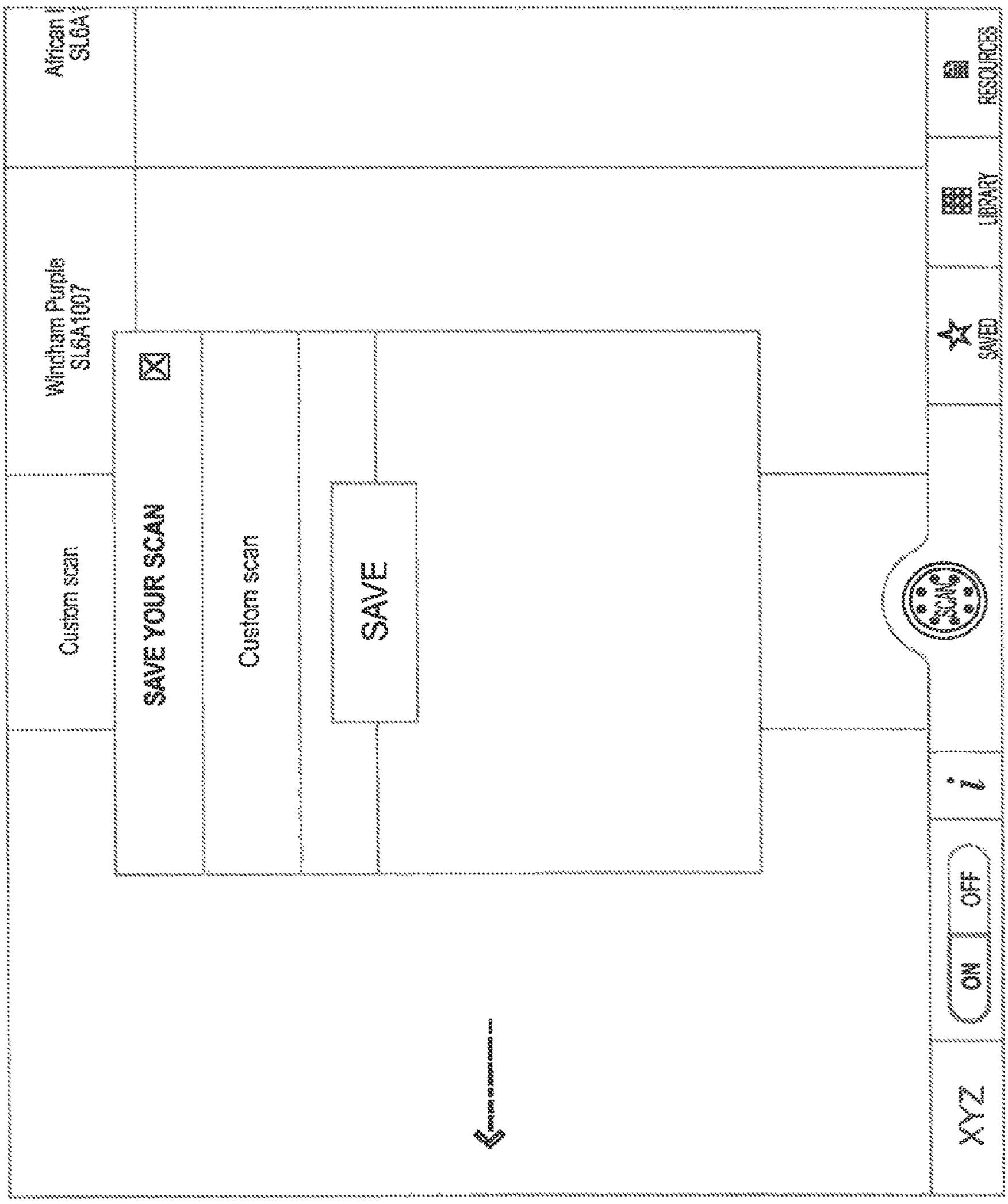
African
SL6A
Windham Purple
SL6A1007
Custom scan
SAVE YOUR SCAN
Custom scan
SAVE
RESOURCES
LIBRARY
SAVED
OFF
XYZ

FIG. 13

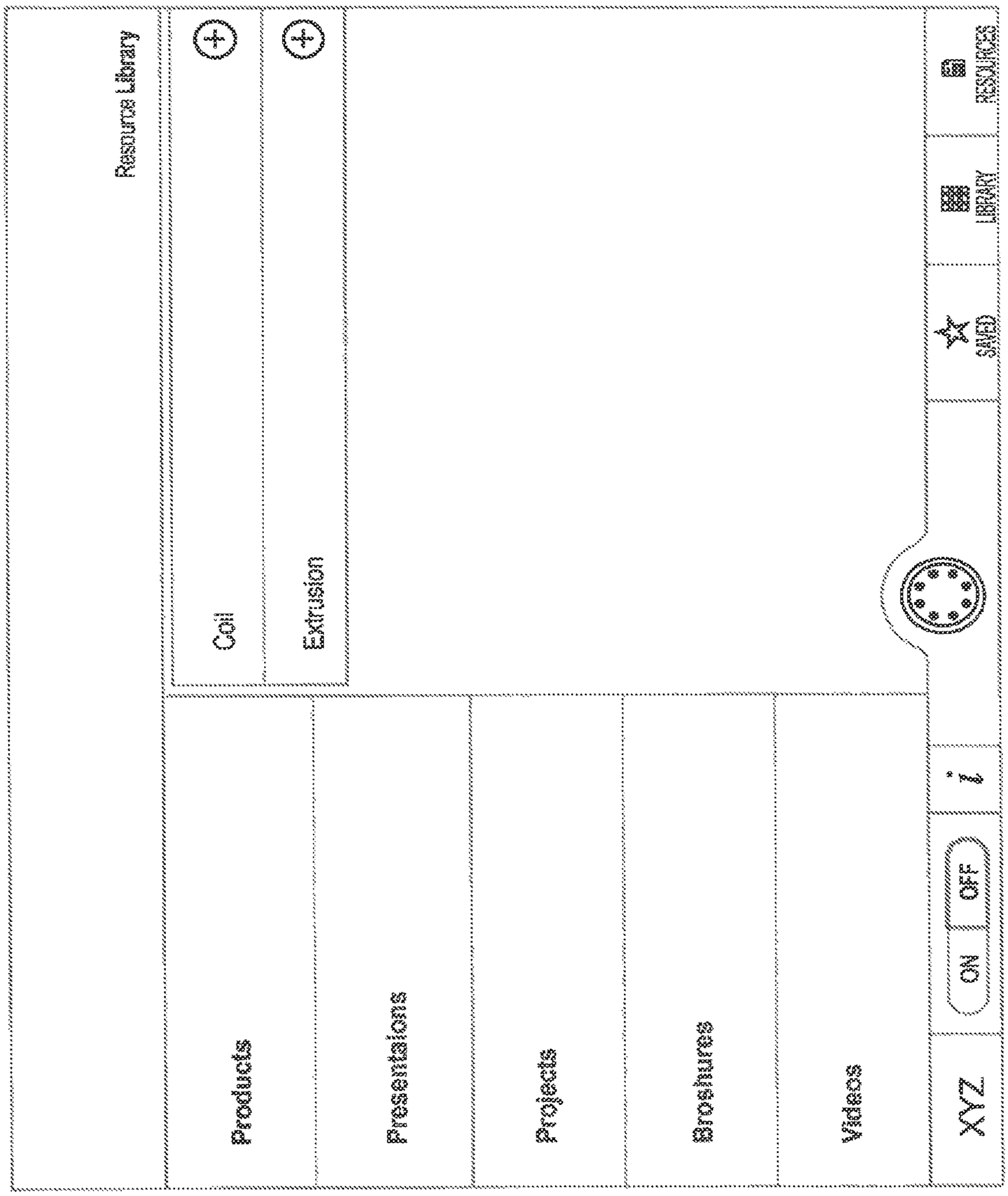
Resource Library
Products
Presentations
Projects
Brochures
Videos
Coil
Extrusion
RESOURCES
LIBRARY
SAVED
XYZ
ON
OFF

FIG. 14

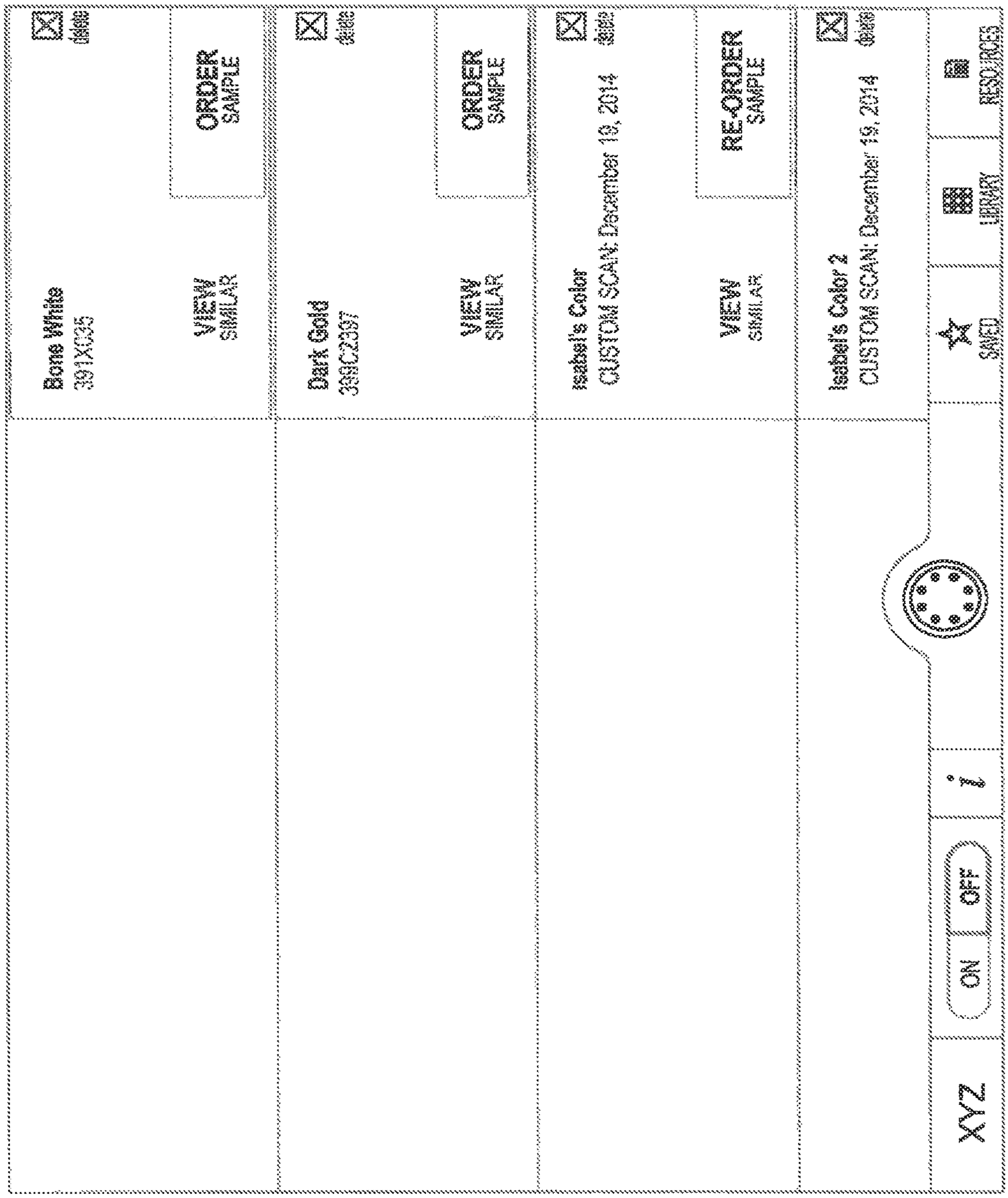
delete
ORDER SAMPLE
Bone White
391X035
VIEW SIMILAR
delete
ORDER SAMPLE
Dark Gold
39GC2397
VIEW SIMILAR
delete
RE-ORDER SAMPLE
Isabel's Color
CUSTOM SCAN: December 19, 2014
VIEW SIMILAR
delete
Isabel's Color 2
CUSTOM SCAN: December 19, 2014
LIBRARY
RESOURCES
SAVED
OFF
ON
ZAX

FIG. 15

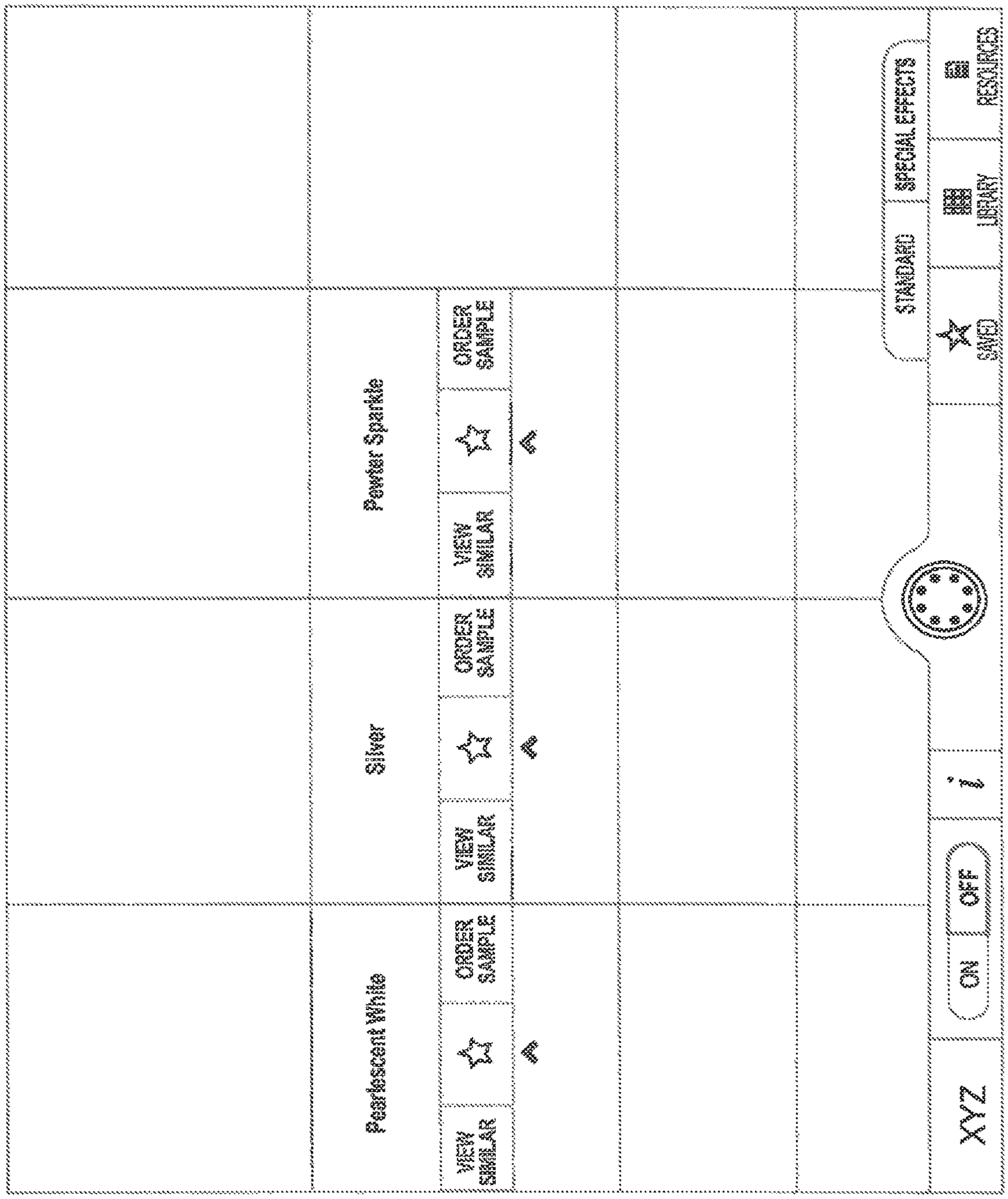
Powter Sparkle
ORDER SAMPLE
VIEW SIMILAR
Silver
ORDER SAMPLE
VIEW SIMILAR
Pearlescent White
ORDER SAMPLE
VIEW SIMILAR
STANDARD
SPECIAL EFFECTS
RESOURCES
LIBRARY
SAVED
ON
OFF
XYZ

FIG. 16

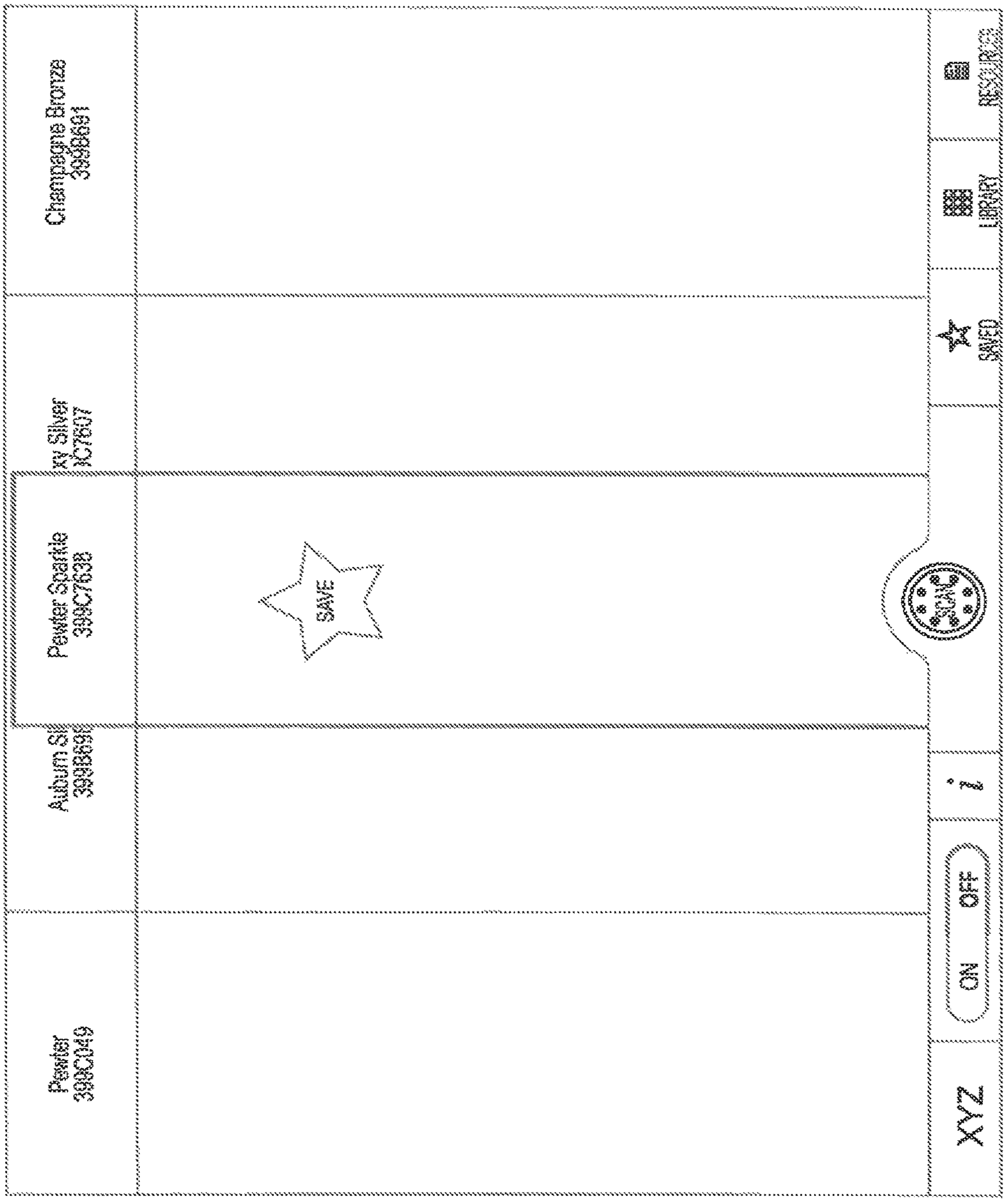
Champagne Bronze
39988691
Auburn Silk
39988691
Pewter Sparkle
399C7638
xv Silver
XC7607
Pewter
398C049
SAVE
RESOURCES
LIBRARY
SAVED
SCAN
?
XYZ
ON
OFF

FIG. 17

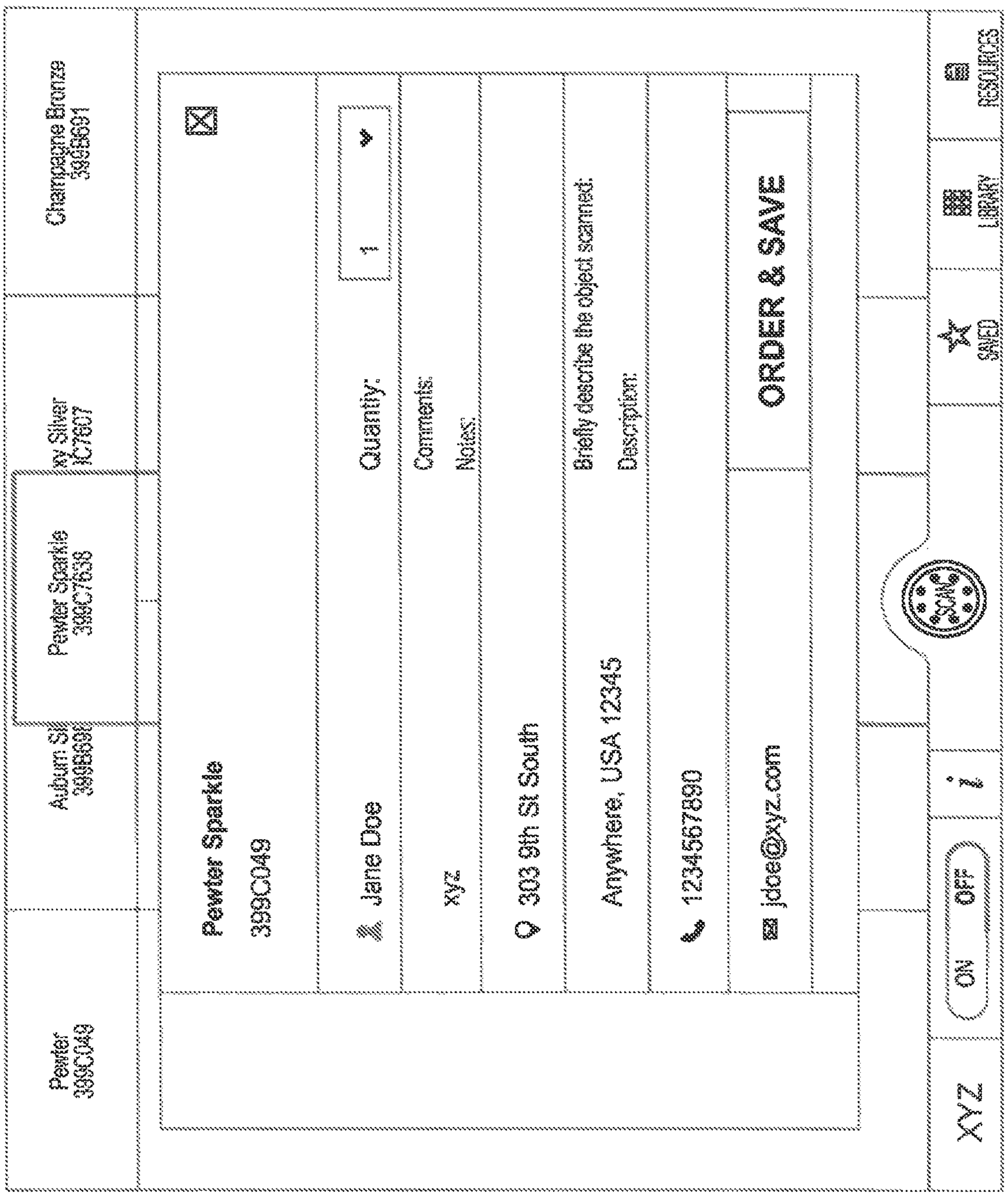
Champagne Bronze
399B691
Auburn Silk
399B691
Pewter Sparkle
399C7638
Ivy Silver
IC7807
Pewter Sparkle
399C049
Jane Doe
303 9th St South
Anywhere, USA 12345
1234567890
jdoe@xyz.com
Quanity:
1
Comments:
xyz
Notes:
Briefly describe the object scanned
Description:
ORDER & SAVE
SAVED
LIBRARY
RESOURCES
SCAN
off
ON
XYZ
Pewter
399C049

FIG. 18

# DIGITAL SYSTEM AND METHOD FOR PAINT COLOR MATCHING

## CROSS REFERENCE TO RELATED APPLICATION

This application is a Continuation of application Ser. No. 15/320,273 filed on Dec. 19, 2016, which is a National Stage filing of International Application No. PCT/US2015/037775 filed on Jun. 25, 2015, which claims priority under 35 U.S.C. 119 (e) to U.S. Provisional Application No. 62/132,672 filed on Mar. 13, 2015 and 62/017,245 filed on Jun. 25, 2014, all entitled "DIGITAL SYSTEM AND METHOD FOR PAINT COLOR MATCHING", the disclosures of all are incorporated herein by reference in their entirety.

## BACKGROUND

Computerized color matching techniques using spectrophotometers can be used to select a paint for a particular application. In these processes a sample of a target color provided by a customer is measured by a color measurement device to obtain digital color information corresponding to the target color. The digital color information is then compared to paint formulas stored in a database to determine a suitable paint formulation to apply to a substrate to obtain the target color.

## SUMMARY

If the digital color information of a target color obtained by a color measurement device is displayed on a display device for approval by a customer, the digital color image of the target color displayed on the display can appear to the customer to be an inaccurate representation of the target color. For example, variations in the digital color image generated by a particular display can cause the displayed digital color information to differ in tint or intensity from the target color observed by the user. These variations between displayed digital colors and actual colors observed by the user can make it difficult for the customer to accurately select a particular paint formulation. In addition, if a paint formula is selected by the customer based on the digital color image on a particular display, the paint formulation can appear to be, based on the customer's perception at the time of purchase, the "wrong" color when later applied to a selected substrate. This can cause the customer to return the paint as an off-shade tint or an erroneous formulation.

In one aspect, the present disclosure is directed to a color correction application run by a computing device. The color calibration and correction tool is configured to adjust the digital image on a color display to accurately and consistently display a target color, which allows users to confidently select a paint color for a particular application.

In one aspect, the present disclosure is directed to a method including:

A) obtaining first color information for each of a plurality of first samples with a color measurement device connected to a computing device comprising a display, wherein the first samples each include a first target color;

B) displaying on the display of the computing device a digital color image of at least one first target color;

C) determining offset values for each first target color such that the digital color image of each first target color matches the corresponding first target color on each of the first samples;



D) scanning a second sample to obtain second color information, wherein the second sample includes a second target color;

E) determining by a processor of the computing device, using the offset values of the first target colors, an interpolated offset for the display such that the digital image of the second target color matches the second target color; and

F) displaying on the display a digital color image of the second target color.

In another aspect, the present disclosure is directed to a method including:

A) obtaining first color information for a plurality of samples with a color measurement device wirelessly connected to a computing device including a display, and wherein the each of the plurality of samples comprises a first target color;

B) displaying on the display of the computing device a first digital color image of the each of the first target colors;

C) displaying on the display of the computing device for each first digital color image a second digital color image including second color information, each of the second digital color images differing in tint or intensity from a first digital color image corresponding to a target color, wherein the second color information for each first target color is shifted from the first color information for each first target color by a first offset value;

D) selecting by the user from the first and the second digital color images displayed on the display of the computing device a selected image perceived by the user to most closely correspond to each first target color;

E) determining, using the selected images, offset values for each first target color such that the digital color image of each first target color matches the corresponding first target color on each of the first samples;

F) scanning a third sample to obtain third color information, wherein the third sample includes a third target color;

G) determining by a processor of the computing device, using the offset values of the first target colors, an interpolated offset for the display such that the digital image of the third target color matches the third target color; and

H) displaying on the display a digital color image of the third target color.

In yet another embodiment, the present disclosure is directed to a system including a mobile computing device selected from a tablet, a smartphone, a digital watch, or a wearable computing device, wherein the mobile computing device includes a display; a color measurement device connected to the mobile computing device; a color offset value database associated with the mobile electronic device display, wherein the offset value data base stores a color offset value representative of the display, and wherein the color offset value is determined by a processor of the mobile computing device by calculating a series of offset values for each of a plurality of first target colors such that the digital color image of each first target color matches the corresponding first target color on each of a series of first samples.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

## BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic block diagram illustrating the components of a color matching system.

FIG. **1**A is a schematic illustration of an example computer architecture for using the color calibration and correction application.

FIGS. **2-3** are flow charts of methods for calculating an offset value for displayed digital color images.

FIG. **4**A is a screen shot of an embodiment of an icon that can be tapped by a user to activate a color matching system.

FIG. **4**B is a screen shot of a display that can be activated by a user to access a color matching system.

FIG. **5** is a screen shot of instructions to assist the user in using the wirelessly connected color measurement device to obtain color information.

FIG. **6-7** are screen shots with instructions for powering on, linking or pairing with the mobile device, and calibrating the color measurement device.

FIG. **8** is a screen shot providing instructions to guide a user in exploring a color library or reviewing previously saved color scans.

FIG. **9** is a screen shot providing a user with instructions for scanning a sample with the color measurement device, while FIG. **10** provides the user with instructions for saving the scanned color information, and FIG. **11** provides the user with ordering information to obtain the scanned color.

FIGS. **12-13** are screen shots of digital color images obtained by scanning or sample or selecting a color from the color library.

FIG. **14** is a screen shot of tools that may be accessed to assist the user in selecting a color from the color library or to provide the user with information on how to utilize the selected color in a painting project.

FIGS. **15-17** are screen shots with instructions guiding the user in selecting, naming, and storing a scanned color or stock color.

FIG. **18** is a screen shot with instructions guiding a customer in ordering a sample of a selected color.

Like symbols in the drawings indicate like elements.

## DETAILED DESCRIPTION

FIG. **1** depicts one possible configuration of a color measurement system that may be used to carry out the color calibration and correction method of the present disclosure. In this depiction, the color measurement system **10** consists of a color measurement device **30** for measuring the color of a region of a sample **20**, a computing device **40** (which is, in some embodiments, a mobile computing device), and an optional tinting machine **60**. A suitable color measurement device **30** may include cameras, scanners, or spectrophotometers, or combinations thereof.

In various embodiments, the color measurement and correction system **10** includes a spectrophotometer that is part of the mobile computing device **40** or is wirelessly linked to the computing device **40** by a communication system such as, for example, a network interface card, an Ethernet card, an optical transceiver, a radio frequency transceiver, or any other type of device that can send and receive information. Other examples of such communication systems may include, but are not limited to, Bluetooth, 4G, 3G, near field communication (NFC), and Wi-Fi radios, Universal Serial Bus (USB) interfaces, etc.

In one embodiment, the spectrophotometer is also a portable device such as those available from Variableinc, Chattanooga, Tenn., under the trade designation NODE. The NODE is a modular device that can be configured with a wide variety of detachable sensor elements for color measurement including, for example, a spectrophotometer, a bar code scanner, a light meter, and the like. The NODE device transmits digital color information about the sample **20** wirelessly through Bluetooth 2.1 or 4.0 up to 250 feet away to an iOS (Apple) or Android smart mobile computing device **40**. Each NODE device also has an internal memory port **32** allowing for data to be stored and then uploaded to any computer or mobile computing device.

In one embodiment, the NODE+ sensor platform, combined with the Chroma 2.1 color sensor (the NODE) is a Bluetooth Low Enemy (BLE) peripheral which can scan an item it is placed on, calculate the CIELAB value of the color of the scanned item, and then communicate that result over BLE. CIE 1976 color space (CIELAB) values are a perceptually uniform extension of the abstract XYZ color space, which represents colors in a way similar to how the colors are represented by the human eye.

A color space is perceptually uniform if a change in a value representing a color would result in a similar change in the visual intensity of the color itself. Perceptual uniformity can simplify the determination of how similar and how different two colors are. A CIELAB color value has three parts: L*, which denotes how light or dark the color is, a*, which denotes how much green or magenta a color has, and b*, which denotes how much blue or yellow a color has.

All CIELAB values specify an illuminant, which is type of light that is hitting the sample being measured. In this application the CIELAB values utilize a D65 illuminant, which closely corresponds to bright noon day sunshine. D65 refers to an illuminant that has a color temperature of approximately 6500 k.

As illustrated, the mobile computing device **40** includes a processor **42** and a user input device such as, for example, a color display **44**. In various embodiments, the computing device **40** may include any number of different portable electronic computing devices, but not limited to, smart watches, smart glasses, headsets, mobile phones (including smartphones), laptop and tablet computers, cameras, personal digital assistants (PDAs), etc. The computing device **40** may include various input and output components, including, e.g. one or more processors, memory, telemetry modules, cellular network antennas, a display, one or more UI elements, sensors, and a power source like a rechargeable battery. One or more application processors may implement functionality and/or execute instructions within the computing device **40**. These instructions executed by application processors may cause the computing device **40** to read/write/etc. information during program execution. Examples of one or more of application processors used in the computing device **40** may include one or more microprocessors, digital signal processors (DSPs), application specific integrated circuits (ASICs), field programmable gate arrays (FPGAs), or any other equivalent integrated or discrete logic circuitry, as well as any combinations of such components.

FIG. **1**A illustrates an example computer architecture for utilizing the color correction application of the present disclosure. In this embodiment, a color correction application is run on a computer **140**, which may be one or more personal computers, laptop computers, server systems, and/or portable media devices such as a smart phone, portable media player, personal digital assistant (PDA), tablet device, and the like. However, the color correction application may alternatively be utilized with a variety of different computer architectures. For example, the color correction application may be stored on one or more servers (e.g., cloud servers), and accessed over the Internet or other network connections by multiple remote computer devices. Accordingly, the term "computer system", with reference to computer applications of the color calibration and correction tool of the present

disclosure may include any suitable computer architecture of one or more computer devices.

In the embodiment shown in FIG. **1**A, the computer **140** may include a user interface **142**, a memory controller **150**, a processor **144**, storage media **152**, input/output (I/O) controller **154**, and network adapter **156**. The computer **140** may also include a variety of additional components that are contained in conventional computers, servers, and/or media devices.

The user interface **142** is a user-operated interface (e.g., keyboards, touch pads, touchscreen displays, and other eye, voice, or hand-operated controls) configured to operate computer **140** and run the color correction application. The memory controller **150** is a circuit assembly that interfaces the components of the computer **140** with one or more volatile random access memory (RAM) modules of storage media **152**. The processor **144** is one or more computer-processing units configured to operate the computer **140**, and optionally, with memory controller **150**, may perform all of the functions for running the color correction application.

The storage media **152** is one or more internal and/or external data storage devices or computer storage media for computer **140**, such as volatile RAM modules, read-only memory modules, optical media, magnetic media (e.g., hard disc drives), solid-state media (e.g., FLASH memory and solid-state drives), analog media, and the like. Storage media **152** may retain an executable copy of the color correction application, referred to as stored executable file **162**, as well as color palette database **164** and paint inventory database **166**. Alternatively, color palette database **164** and/or paint inventory database **166** may be located on one or more remote computer devices (e.g., a cloud server), or may be incorporated into stored executable file **162** of the color correction application.

The I/O controller **154** is a circuit assembly that interfaces memory controller **150**, processor **144**, and storage media **152** with various input and output components of computer **140**, including network adapter **156**. The network adapter **156** is one or more wired or wireless transmitter/receiver adapters configured to communicate over a network line **157**. For example, network adapter **156** may be a direct local area network or internet connection adapter, a cellular wide area network transmitter/receiver, a Wi-Fi local area network transmitter/receiver, or combinations thereof.

Referring again to FIG. **1**, the computing device **40** may be configured to access a storage device **50** housing database records of paint formulations, colors and the like. In addition, the computing device **40** may be a networked device linked to a database of paint formulations and colors. In various embodiments, the storage device **50** can include a wide variety of databases, including databases of color information obtained from paint formula books, previously saved customer paint formulations, or color fan decks obtained from various manufacturers.

Any suitable tinting machine **60** may be utilized that is capable of delivering known quantities of various ingredients. Preferred systems are in communication with the computing device **40** and the storage device **50**, but "stand-alone" systems and "manual" systems may also be used. In such instances the desired paint formula information obtained from the data storage device **50** and output from the computing device **40** is used to produce a desired paint color.

When the target color obtained by scanning the sample or obtained by selecting a stock color from a fan deck, color book or catalogue is displayed on the display **42** of the computing device **40** as a digital color image, the customer can perceive the digital color image to have a slightly different color from the target color of the sample or fan deck. This slight difference in tint or intensity, or both can cause the customer to select an incorrect paint formulation, or can cause the customer discomfort in even making a paint formulation selection. These differences can result from variations in displays, which can be difficult or inconvenient for the customer to adjust for accurate color matching.

The present disclosure is directed to display-specific color correction methods and applications to ensure that the digital color image of a target color on the display **42** of the mobile computing device **40** accurately represents a target color measured by a color measurement device.

In one embodiment shown in FIG. **2**, a method **100** includes a step **102** of obtaining color information for a sample with a color measurement device associated with a mobile computing device including a display. The sample has a target color. In some embodiments, the samples are primary colors such as, for example, red, green, blue, yellow, purple, black and white. In some embodiments, the samples are of a known color. In various embodiments, the samples can be solid colors, metallic colors, and combinations thereof.

In step **104**, a series of offset values for the target color are determined to adjust the digital color image of the target color on the display **42** to match the corresponding target color on the sample.

In one embodiment, for example, the offset values can be determined converting the CIELAB values obtained by the color measurement device for the sample to digital red/green/blue (RGB) values. The RGB color space is a color space used by commercially available mobile devices such as the iPad for displaying colors to a viewer.

For example, the RGB values can be used to adjust the appearance of the target color on a selected display under indoor lighting conditions. Since indoor lighting usually ranges from a color temperature of about 2800 k to about 4500 k, about 3400 k is a common approximation for the color temperature of indoor lighting. In one embodiment, the RGB values calculated from the CIELAB values obtained from the color measurement device are adjusted for color accuracy on a selected mobile device display using software packages such as, for example, those available under the trade designation Capture One from Phase One USA, Melville, N.Y., by comparing the digital image on the display to the physical display panel under 3400K lighting.

In various embodiments, to obtain suitably accurate color adjustments the mobile device display was viewed at an angle of about 65°, away from natural sunlight, at a mobile device brightness of 100%, although a wide variety of viewing conditions could potentially be used.

The adjusted RGB values of the target color are then used to determine an offset value for the selected display for each target color. The corrected RGB colors were determined and stored in a database so that a selected mobile device display (for example, an iPad) displaying the corrected sRGB color would display a color on the screen that is the most perceptually similar to a physical sample of the target color being illuminated by a 3400 k light source.

In step **106**, using the offset color values, the digital color image of the target color of the sample is displayed on the display of the mobile device, and the digital color image of the target color matches the corresponding target color on the sample.

In optional step **108**, a second sample is scanned with the color measurement device to obtain second color information, wherein the second sample is of a second target color. In step **112**, using the series of offset RGB values of the first

target colors, an interpolated offset for the display for a particular mobile device is calculated by the processor of the computing device such that the digital image of the second target color on the screen of the mobile device matches the second target color. For example, if the second color is orange, the processor in the computing device can utilize the offset values for red and yellow to determine a suitable offset for orange. The more samples of the first target color are analyzed, the greater the system's ability to generate more accurate interpolated or extrapolated offset values for various colors.

In another example embodiment, a color correction algorithm may be used by the processor of the computing device to calculate the ΔE distance between the CIELAB value of a scanned target color, and the CIELAB value of every other color in a paint color library. Δe (deltaE) is a measurement of the perceptual distance between two colors in the CIELAB color space. The smaller the deltaE, value between two colors, the closer they are together. A ΔE of 1.0 is usually the smallest perceivable difference between two colors. There are several standards for calculating ΔE, and in one example embodiment, which is not intended to be limiting, the color correction algorithm uses de2000, which varies the weighting of L* depending on where in the lightness range the color falls.

In one embodiment, the color calibration and correction application running on the processor of the computing device selects a plurality (for example, 3, 5, 10, 50 or 100) of closest colors in the color library with the smallest ΔE values relative to the scanned target color. The closest colors are the most perceptually similar to the scanned target color, and in some embodiments the digital color images of the closest colors in the color library are displayed adjacent to the scanned target color.

In one embodiment, a color correction application running on the processor of the computing device loops through each of the plurality of closest colors and, for each closest color:

a. If ΔE between the scanned CIELAB color and the closest color is less than ε (0.000001), set ΔE to ε.
b. Create a weight for each color to indicate how much this color should affect the correction of the scanned color. The weight is calculated using the formula 1/ΔE.
c. Calculate an uncorrected sRGB color from the original CIELAB scan of the closest color. The algorithm now has the uncorrected RGB color and the hand corrected RGB color for the closest color.
d. Create a correction factor for each red, green, and blue display component of the closest color. The correction factors are in the form:

i. $Cf_r = \frac{\text{hand-corrected red}}{\text{uncorrected red}}$

ii. $Cf_g = \frac{\text{hand-corrected green}}{\text{uncorrected green}}$

iii. $Cf_b = \frac{\text{hand-corrected blue}}{\text{uncorrected blue}}$

e. Each correction factor is multiplied by the weight determined in step b.
f. The red correction factor ($Cf_r$) is added to a running total of all red correction factors. The same is done with the green and blue correction factors.
g. The weight calculated in step b is added to a total of all weights.

The total of all red correction factors is divided by the total of all weights. This gives the weighted average of the red correction factor.

The weighted average is determined in the same way with the green and blue color components.

The weighted average of the red correction factor is multiplied with the uncorrected red component of the scanned color. This creates a corrected red component for the scanned color.

The same process is used by the processor of the computing device to create corrected green and blue components for the scanned color.

The corrected red, green, and blue components of the scanned second target color are combined by the processor of the computing device into a RGB color, which is then displayed on the screen of the mobile device.

In an optional step, the color measurement device may be calibrated prior to scanning the first target color samples to obtaining the first color information.

In step **114**, if the computing device **40** is connected to a database of paint formula information, in some embodiments the method further optionally includes matching the target color information to paint formula information in the database **50** to determine a sample paint formula to provide the target color on the sample. In various embodiments, the sample paint formula is selected from a compilation of stock formulas, a record of formulas previously prepared for a user, or a fan deck of colors.

In step **116**, the method can further include the optional step of permitting a user to place an order for the sample paint formula from the computing device.

In step **118**, the method can further include the optional step of sending to the user a painted article painted with the sample paint formula.

In another embodiment of the method **200** shown in FIG. **3**, in step **202** first color information is obtained for a plurality of samples with a color measurement device wirelessly connected to a mobile computing device including a display, wherein the each of the plurality of samples includes a first target color.

In step **204**, a first digital color image of the each of the first target colors is displayed on the display of the mobile computing device.

In step **206**, for each first digital color image, one or more second digital color images including second color information is displayed by the mobile computing device on the display, each of the second digital color images differing in tint or intensity from a first digital color image corresponding to a target color, wherein the second color information for each first target color is shifted from the first color information for each first target color by a first offset value. In various embodiments, the second color information differs in tint or intensity from the first color information by at least about 1ΔE, or at least 2ΔE, or at least 5ΔE.

In step **208**, a user is permitted to select from the first and the second digital color images displayed on the display of the computing device a selected image perceived by the user to most closely correspond to each first target color. In some embodiments, the user could be allowed to select on the screen the most accurate digital color images that correspond to each first target color.

In step **210**, using the selected images, a series of offset values is determined for each first target color such that the digital color image of each first target color matches the corresponding first target color on each of the first samples

In step **212**, a third sample is scanned to obtain third color information, wherein the third sample includes a third target color, and in step **214** a digital color image of the third target color is displayed on the display.

In step **214**, using the series of offset values of the first and second target colors, an offset for the display is determined by the processor of the computing device using the color correction application above such that the digital image of the third target color matches the third target color.

In yet another embodiment, a user can scan an object and view an accurate color representation of the object displayed by applying the color offset values determined by processor of the computing device using the algorithm above. The user can save the color, order a display panel painted with the color, or view similar colors from the paint color library.

As noted above, the system can be configured to permit the manipulation of database and/or target color images. In one embodiment, the computing device displays a side-by-side comparison of the target panel image next to a database image. The user is then able to scroll through various database images to find the best "match." In another embodiment, the computing device is configured to display an array of database images, graduated pixels, or a scroll bar to adjust colors surrounding the target panel image. The user can use the visual clues of the array to better steer through the array and find the closest "match."

In yet another embodiment, the computing device provides "tools" to enable the user to find other suitable database images. For example, a side-by-side display of the target panel image and a database image might be presented on the display. Tools that permit the user to find other images (e.g., lighter-darker; more red-less red, more green-less green, etc.) are included. The system may also provide a content library including, but not limited to, videos, presentations, case studies and product literature.

In yet another embodiment, the computing device is configured so that more than one database image may be selected as "matches." For example, the user may decide that the best color is somewhere between two displayed database images. The sample color information may be matched by the computing device with paint formula information in the database **50** to determine a sample paint formula to provide the sample color. The paint formula may be provided either as a printout or supplied as directions to an associated tinting machine **60** (FIG. **1**), or a painted sample may be provided to the customer.

In one example embodiment of the color correction application that is not intended to be limiting, once an appropriate icon on the display of the mobile device, such as a "Design Flight" icon in FIG. **4**A or display illustrated in FIG. **4**B is selected by a user, the mobile device begins running the "Design Flight" application, which includes the color correction application described above.

As shown in FIG. **5**, the Design Flight application includes instructions to assist the user in employing the wirelessly connected NODE spectrophotometer device to obtain color information from any colored surface and create an accurate visual color match from an existing formulation or with a custom formulation.

Referring to FIGS. **6-7**, the NODE spectrophotometer device can be powered on, linked or paired with the mobile device.

As shown in FIG. **8**, the user may browse a color library stored in or linked to the data storage device **50**, or may review previously saved scans stored therein. The color library contains a plurality of colors from various manufacturers and may hundreds or thousands of colors. The user would optionally need to scan their colors with their node device and thereby facilitate custom color lookup. The user may swipe left or right to view the colors and previously saved scans, and may tap to select a color.

Referring to FIG. **9**, if a color match to a particular customer-provided or customer approved sample is desired, the user may scan a surface of the sample using the NODE spectrophotometer device. In various embodiments, to obtain the most appropriate regions of the target panel image, the user may be guided to select the appropriate region, or filters may be applied to the entire image to assist or direct that process. For example, in one embodiment, the target panel image is displayed on the display of the computing device and the user is permitted to select those pixels that he or she would like to match. Alternatively, the computing device can highlight the best regions and get confirmation of this selection from the user. The custom color match may be viewed by the customer and saved as shown in FIG. **10**, and the customer may order custom colors as shown in FIG. **11**.

As shown in FIGS. **12-13**, in one embodiment the color display of the computing device can display a digital color image determined using the color correction application described above, and the digital color image obtained from the scan of the sample will be displayed adjacent to digital images of similarly tinted colors from the color library stored in the database **50** (FIG. **1**). The customer can save the scanned or selected color, or an order form may be displayed so the customer can order a paint of the selected color.

Referring to FIG. **14**, the customer may optionally tap an appropriate bar to select tools or other information to assist in the color selection process. Suitable tools include, for example, information on paint products, presentations on how to apply paints, decorating tips and the like, sample project ideas, brochures, and video presentations.

As shown in FIGS. **15-17**, the customer may scan a sample and the scanned color may be displayed adjacent to solid or metallic colors obtained from a paint color library. As shown in FIG. **18**, the customer may then save the scan of the sample and/or order a paint with the appropriate color.

Embodiment 1. A method, comprising: A) obtaining first color information for each of a plurality of first samples with a color measurement device wirelessly connected to a computing device comprising a display, wherein the first samples each comprise a first target color; B) displaying on the display of the computing device a digital color image of at least one first target color; C) determining an offset value for each first target color such that the digital color image of each first target color matches the corresponding first target color on each of the first samples; D) scanning a second sample to obtain second color information, wherein the second sample comprises a second target color; E) determining by a processor of the computing device, using the offset values of the first target colors, an interpolated offset for the display such that the digital image of the second target color matches the second target color; and F) displaying on the display a digital color image of the second target color.

Embodiment 2. The method of embodiment 1, wherein the first samples each comprise known color information.

Embodiment 3. The method of embodiments 1 or 2, further comprising calibrating the color measurement device prior to obtaining the first color information.

Embodiment 4. The method of any of embodiments 1 to 3, wherein the computing device is associated with a database of paint formula information, the method further comprising matching the second color information to paint

formula information in the database to determine a sample paint formula to provide the target color on the second sample.

Embodiment 5. The method of embodiment 4, wherein the sample paint formula is selected from a compilation of stock formulas, a record of formulas previously prepared for a user, or a fan deck of colors.

Embodiment 6. The method of embodiment 4, further comprising permitting the user to place an order for the sample paint formula from the computing device.

Embodiment 7. The method of embodiment 6, further comprising sending to the user a painted article painted with the sample paint formula.

Embodiment 8. The method of any of embodiments 1 to 7, wherein the computing device is selected from a tablet, a smartphone, a digital watch, or a wearable device.

Embodiment 9. The method of any of embodiments 1 to 8, wherein the color measurement device comprises a spectrophotometer.

Embodiment 10. A method, comprising the steps of: A) obtaining first color information for a plurality of samples with a color measurement device wirelessly connected to a computing device comprising a display, and wherein the each of the plurality of samples comprises a first target color; B) displaying on the display of the computing device a first digital color image of the each of the first target colors; C) displaying on the display of the computing device for each first digital color image a second digital color image comprising second color information, each of the second digital color images differing in tint or intensity from a first digital color image corresponding to a target color, wherein the second color information for each first target color is shifted from the first color information for each first target color by a first offset value; D) selecting by the user from the first and the second digital color images displayed on the display of the computing device a selected image perceived by the user to most closely correspond to each first target color; E) determining, using the selected images, offset values for each first target color such that the digital color image of each first target color matches the corresponding first target color on each of the first samples; F) scanning a third sample to obtain third color information, wherein the third sample comprises a third target color; G) determining by a processor of the computing device, using the offset values of the first target colors, an interpolated offset for the display such that the digital image of the third target color matches the third target color; and H) displaying on the display a digital color image of the third target color.

Embodiment 11. The method of embodiment 10, further comprising calibrating the color measurement device prior to obtaining the first color information.

Embodiment 12. The method of any of embodiments 10 to 11, wherein the computing device is selected from a tablet, a smartphone, a digital watch, or a wearable device.

Embodiment 13. The method of any of embodiments 10 to 12, wherein the color measurement device comprises a spectrophotometer.

Embodiment 14. The method of any of embodiments 10 to 13, wherein the computing device is connected to a database of paint formula information, the method further comprising matching the third color information to the paint formula information to determine a sample paint formula to provide the color of the third sample.

Embodiment 15. The method of embodiment 14, wherein the sample paint formula is selected from a compilation of stock formulas, a record of formulas previously prepared for the user, or a fan deck of colors.

Embodiment 16. The method of embodiment 14, further comprising permitting the user to place an order for the sample paint formula from the computing device.

Embodiment 17. A system, comprising: a mobile electronic device selected from a tablet, a smartphone, a digital watch, or a wearable computing device, wherein the mobile electronic device comprises a display; a color measurement device connected to the mobile electronic device; a color offset value database associated with the mobile electronic device display, wherein the offset value data base stores a color offset value representative of the display, and wherein the color offset value is determined by a processor of the mobile electronic device by calculating a series of offset values for each of a plurality of first target colors such that the digital color image of each first target color matches the corresponding first target color on each of a series of first samples.

Embodiment 18. The system of embodiment 17, further comprising a database of paint formula information associated with the mobile electronic device.

Embodiment 19. The system of any of embodiments 17 to 18, further comprising a database of ordering information associated with the mobile electronic device.

Embodiment 20. The system of any of embodiments 17 to 19, further comprising a device for dispensing colorants or vehicles to create a sample color.

In one or more examples, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium and executed by a hardware-based processing unit. Computer-readable media may include computer-readable storage media, which corresponds to a tangible medium such as data storage media, or communication media including any medium that facilitates transfer of a computer program from one place to another, e.g., according to a communication protocol. In this manner, computer-readable media generally may correspond to (1) tangible computer-readable storage media which is non-transitory or (2) a communication medium such as a signal or carrier wave. Data storage media may be any available media that can be accessed by one or more computers or one or more processors to retrieve instructions, code and/or data structures for implementation of the techniques described in this disclosure. A computer program product may include a computer-readable medium.

By way of example, and not limitation, such computer-readable storage media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage, or other magnetic storage devices, flash memory, or any other medium that can be used to store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if instructions are transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. It should be understood, however, that computer-readable storage media and data storage media do not include connections, carrier waves, signals, or other transitory media, but are instead directed to non-transitory, tangible storage media. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD),

floppy disk and Blu-ray disc, where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

Instructions may be executed by one or more processors, such as one or more digital signal processors (DSPs), general purpose microprocessors, application specific integrated circuits (ASICs), field programmable logic arrays (FPGAs), or other equivalent integrated or discrete logic circuitry. Accordingly, the term "processor," as used herein may refer to any of the foregoing structure or any other structure suitable for implementation of the techniques described herein. In addition, in some aspects, the functionality described herein may be provided within dedicated hardware and/or software modules configured for encoding and decoding, or incorporated in a combined codec. Also, the techniques could be fully implemented in one or more circuits or logic elements.

Various embodiments of the invention have been described. These and other embodiments are within the scope of the following claims.

The invention claimed is:

**1**. A method of paint color matching, comprising with a computing device:

obtaining respective first color information for one or more first color samples, wherein the first color samples each comprise a respective first target color;

displaying on a display of the computing device, a first digital color image of at least one of the first color samples using the respective first color information;

receiving a user selected adjustment to the first digital color image, to provide corrected digital color image that is perceived by the user to match the respective first target color of the first color sample, wherein the corrected digital color image comprises first corrected color information;

determining a color offset value for the display corresponding to differences between the first color information and the first corrected color information;

obtaining a second color information of a second color sample, wherein the second color sample comprises a second target color;

determining a second corrected color information using the color offset value and the second color information;

displaying on the display of the computing device a second digital color image of the second color sample using the second corrected color information;

determining one or more reference colors that closely match the second color information, wherein each reference color comprises reference color information and a reference paint formula in the paint formula database;

displaying on the display of the computing device one or more reference digital color images, wherein each reference digital color image corresponds to a respective reference color and is adjusted using the reference color information and the color offset value;

receiving one or more user selected reference digital color images; and

providing the target paint formula information based on the reference paint formulas of the one or more user selected reference digital color images.

**2**. A method of paint color matching, comprising with a computing device:

obtaining respective first color information for one or more first color samples, wherein the first color samples each comprise a respective first target color;

displaying on a display of the computing device, a first digital color image of at least one of the first color samples using the respective first color information;

receiving a user selected adjustment to the first digital color image, to provide corrected digital color image that is perceived by the user to match the respective first target color of the first color sample, wherein the corrected digital color image comprises first corrected color information;

determining a color offset value for the display corresponding to differences between the first color information and the first corrected color information;

obtaining a second color information of a second color sample, wherein the second color sample comprises a second target color;

determining a second corrected color information using the color offset value and the second color information;

displaying on the display of the computing device a second digital color image of the second color sample using the second corrected color information; and

matching the second color information to paint formula information in a paint formula database to determine target paint formula information corresponding to the second target color.

**3**. The method of claim **2**, wherein obtaining the second color information comprises scanning the second target color with a spectrophotometer device connected to the computing device.

**4**. The method of claim **3**, wherein the spectrophotometer is selected from a portable device.

**5**. The method of claim **3**, wherein the spectrophotometer device is wirelessly connected to the computing device.

**6**. The method of claim **2**, wherein the second color information comprises CIELAB data.

**7**. The method of claim **6**, wherein determining the second corrected color information comprises converting the CIELAB data into RGB data and applying the color offset value to the RGB data to obtain the second corrected color information.

**8**. The method of claim **2**, wherein matching the second color information to paint formula information in the paint formula database comprises:

determining one or more reference colors that closely match the second color information, wherein each reference color comprises reference color information and a reference paint formula in the paint formula database;

displaying on the display of the computing device one or more reference digital color images, wherein each reference digital color image corresponds to a respective reference color and is adjusted using the reference color information and the color offset value;

receiving one or more user selected reference digital color images; and

providing the target paint formula information based on the reference paint formulas of the one or more user selected reference digital color images.

**9**. The method of claim **8**, wherein determining the one or more reference colors that closely match the second color information comprises:

comparing CIELAB data of the second color information to respective CIELAB data of a plurality colors in the paint formula database;

selecting, from the plurality of colors, the one or more reference colors having respective CIELAB data closest to the CIELAB data of the second color.

10. The method of claim 8, wherein the target paint formula is selected from a compilation of stock formulas, a record of formulas previously prepared for a user, or a fan deck of colors.

11. The method of claim 8, further comprising ordering the target paint formula from the computing device.

12. The method of claim 8, wherein receiving the one or more user selected reference colors comprises receiving, by the computing device, at least two user selected reference colors perceived by the user to closely match the second target color.

13. The method of claim 12, wherein providing the target paint formula information comprises determining a custom paint formula based on the reference paint formulas of the at least two user selected reference colors.

14. The method of claim 13, further comprising sending instructions to produce a custom paint sample based on the custom paint formula.

15. The method of claim 2, wherein obtaining the respective first color information for each of the one or more first color samples comprises scanning a respective first color sample with a spectrophotometer device connected to the computing device.

16. The method of claim 2, wherein the respective first color information comprise RGB data, and wherein the color offset value comprises an RGB correction that is applied to the RGB data to produce the first corrected color information.

17. The method of claim 2, wherein the computing device is selected from a tablet, a smartphone, a digital watch, or a wearable device.

18. The method of claim 2, wherein the computing device is selected from a tablet or smartphone.

19. A system, comprising:

a mobile electronic device selected from a tablet, a smartphone, a digital watch, or a wearable computing device, wherein the mobile electronic device comprises a display; and

a spectrophotometer connected to the mobile electronic device;

wherein the mobile electronic device is configured to:

display on the display, a first digital color image of a first color sample using first color information obtained by the spectrophotometer, wherein the first color sample comprises a first target color;

receive a user selected adjustment to the first digital color image to display a corrected digital color image that is perceived by the user to match the first target color for the first color sample, wherein the corrected digital color image comprises first corrected color information;

determine a color offset value for the display corresponding to differences between the first color information and the first corrected color information;

receive second color information from the spectrophotometer obtained from a scan of a second color sample, wherein the second color sample comprises a second target color;

apply the color offset value to the second color information to determine second corrected color information;

display on the display, a second digital color image of the second color sample using the second corrected color information; and

match the second color information to paint formula information in a paint formula database to determine target paint formula information corresponding to the second target color.

20. The method of claim 19, wherein the mobile electronic device is further configured to:

determine one or more reference colors stored in the paint formula database that closely match the second color information, wherein each reference color comprises reference color information and a reference paint formula in the paint formula database;

display on the display one or more reference digital color images, wherein each reference digital color image corresponds to a respective reference color and is adjusted using the reference color information and the color offset value;

receive an input from the user selecting one or more of the displayed reference digital color images; and

use the reference paint formulas corresponding to the one or more user selected reference digital color images to provide the target paint formula information.

21. The method of claim 20, wherein the mobile electronic device is further configured to:

compare CIELAB data of the second color information to respective CIELAB data of a plurality colors in the paint formula database; and

select, from the plurality of colors, the one or more reference colors having respective CIELAB data closest to the CIELAB data of the second color.

22. The method of claim 20, wherein the mobile electronic device is configured to:

receive at least two user selected reference colors perceived by the user to closely match the second target color; and

determine a custom paint formula based on the reference paint formulas of the at least two user selected reference colors.

23. The system of claim 19, further comprising a database of paint ordering information associated with the mobile electronic device.

24. The system of claim 19, further comprising a device for dispensing colorants or vehicles to create a paint sample using the target paint formula.

25. The system of claim 19, wherein the spectrophotometer is a portable device.

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